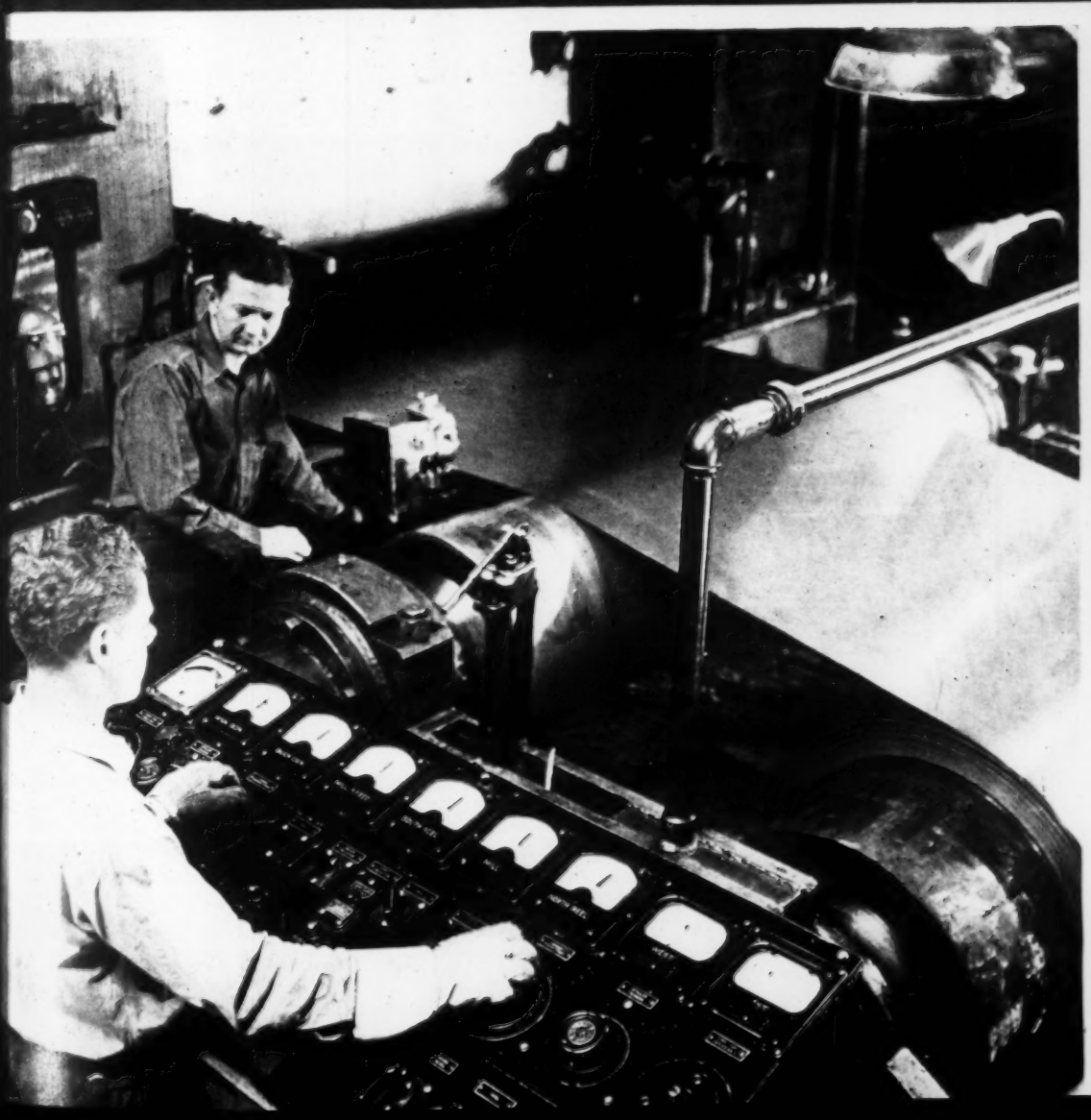
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



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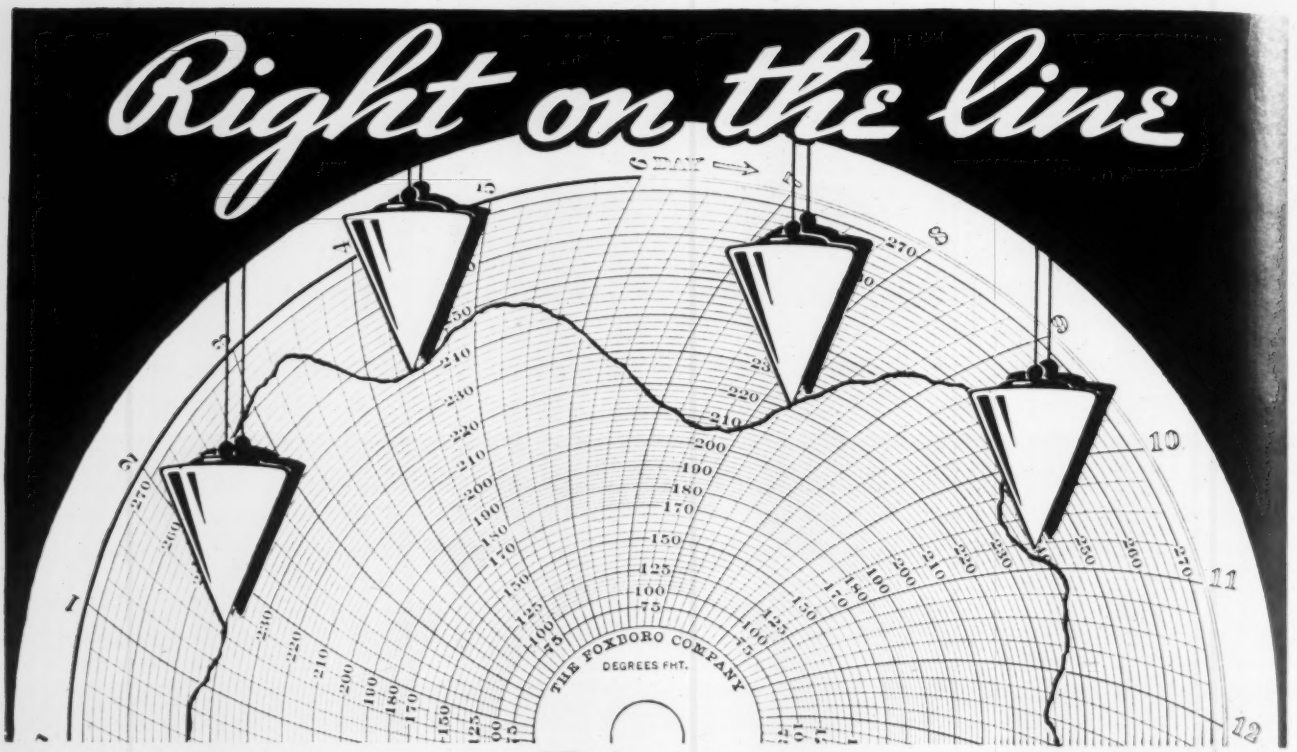
Right on the line



with unvarying accuracy and unequaled speed

Glance at the tabulation below. It's an accurate comparison of the time taken to cover the same portion of the scale of five recording thermometers of the same type, but of different manufacture. This superior Foxboro Thermometer assures you the necessary speed to record any process temperature change.

RESPONSIVENESS CHART		
INSTRUMENT	TIME TAKEN TO COVER EQUAL PORTION OF CHART SCALE	PER CENT RESPONSIVENESS
FOXBORO RECORDING THERMOMETER	15 SECONDS	100%
RECORDING THERMOMETER A	32 SECONDS	47%
RECORDING THERMOMETER B	42 SECONDS	37%
RECORDING THERMOMETER C	33 SECONDS	45%
RECORDING THERMOMETER D	85 SECONDS	18%

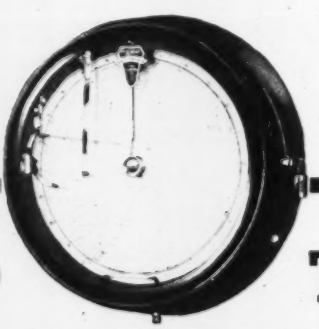
Responsiveness, which complements Foxboro accuracy, is clearly shown in the table above—a record of the time taken to cover the same portion of the scale of five Recording Vapor Pressure Type Thermometers of different manufacture. Foxboro thermometers are more responsive under all bulb installation conditions.

Hand-in-hand with this unapproached response Foxboro gives you bull's-eye accuracy over the entire chart range — not merely single point calibration. It is the combination of these two qualities that guarantees a precise time-temperature record, a precision which can be attained in no other way.

Foxboro certifies each instrument. The quality of workmanship, the design, and engineering skill all aid in assuring this unequaled response and accuracy over long periods of time.

For truly economical performance users in every branch of industry agree that it pays to specify Foxboro. Write for Bulletin 198.

THE FOXBORO COMPANY
46 Neponset Avenue
Foxboro, Mass., U.S.A.
Branches in 25 Principal Cities



FOXBORO THERMOMETERS

ACCURACY FOXBORO *RESPONSE*

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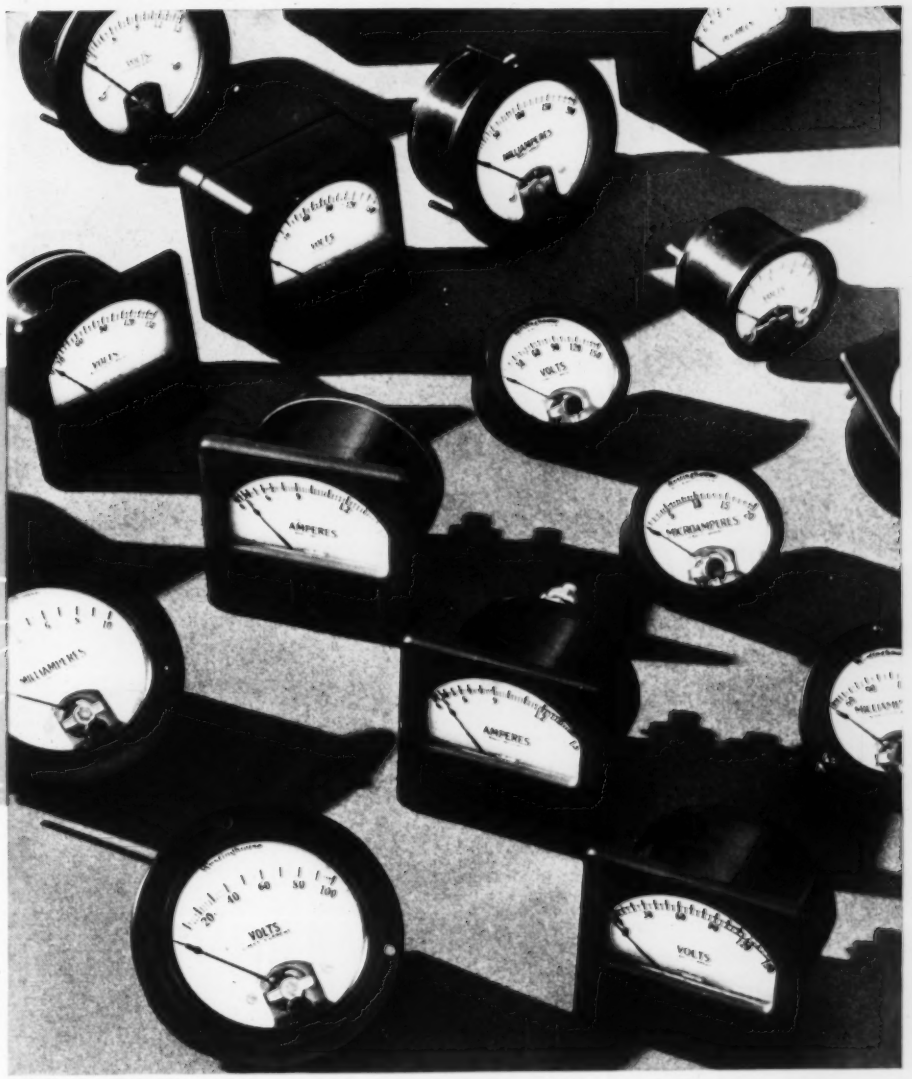

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Accuracy, durability, and ease of reading have marked Westinghouse instruments since 1888. These features are essential in any high class instrument. But today, discriminating buyers are demanding that the appearance of an instrument match its built-in quality.

Westinghouse miniatures are outstandingly clean cut. Their simplicity of line fits them for the finest panels, switchboards, electrified machinery, etc.

Made in both round and square designs, Westinghouse miniatures are available in direct-current, rectox, thermocouple, and radio-frequency types. The entire line has but two types of mechanisms. This assures the interchangeability of parts that promotes short-delivery dates on special and semi-standard forms.

For detailed information, ask for Miniature Instrument Catalog, Room 5-N, East Pittsburgh, Pa.

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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Courtesy *U. S. Steel News*

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

The benefits of teamwork are illustrated by this month's first five articles. We are privileged to publish them by reason of our cooperation with the SAE, the Forest Products Laboratory, the National Bureau of Standards, the NACA, etc. Our part is merely to bring together those who can define a problem, those who can describe the instrumental solution and those who can manufacture it: these are the three groups deserving credit. Some of the articles report fine teamwork done before we were asked to step into the picture.

There's a fourth group: readers who tell their local newspapers about *Instruments* articles of public interest. Several have thus given general publicity to previous Driving Skill and Riding Comfort articles and have sent us the newspaper clippings. Good work!

Brown's Table I (page 279) and Tea's reports (page 281) are of particular value. But why don't experts rate the *frequency factor?* We find 2 c.p.s. most comfortable and are disturbed by oscillations >20% faster or slower (other things equal). So, no doubt, do most other drivers whose walking cadence is normal.

Ralph Batcher continues explaining how to make a cathode-ray tube draw pictures of cyclic phenomena.

The "control" part of "Electrical Measurements and Control" concludes this month.

THE MODEL BASIN

In last month's editorial we presented the case of America's need for a modern Model Basin. It has been a pleasure to receive your thanks—a joy to receive letters from such men as, for instance, Admiral Land, the Navy's Chief Constructor. We made a slip, though: Congressman Vinson, the patriotic Chairman of the House Naval Affairs Committee, tells us that the Model Basin Bill itself *was* enacted; what is now necessary is the *appropriation of funds*, "not to exceed $3,500,000" as the Act reads. So please write to your Senators and Representatives, reminding them that this amount is urgently needed to start the construction of a laboratory much needed for National Defense.

"ANY QUESTIONS?"

IN the course of your measurement and control work, you meet problems every single day. Some are both easy and unimportant, like deciding whether to use rubber tubing or install permanent copper tubing. Some are important, especially when they have a bearing on production costs or on the outcome of a research project. In such cases, whether the problem seems easy or difficult, you seek not merely "an answer" but "the One Best Way"; you do not make a snap decision but search your memory, your notes, your bookshelves and data files; and sometimes you communicate with other departments or with outside sources of information, such as *Instruments*.

So do four thousand other readers.

On the other hand, you probably have solved in the past a special problem which another reader meets today for the first time.

In next month's issue we shall inaugurate a Questions and Answers Department: The questions will be brief extracts from subscribers' letters handled by our Information Department; the answers will be extracts from replies prepared by our staff. The subjects will all be of interest to many readers.

In the January 1937 issue there will be inaugurated another new department, called INSTRUMENTATION FORUM and conducted somewhat like a Q&A Department but devoted to longer discussions (particularly where illustrations are required) and with these important differences:

Only one subject will be discussed each month. Each question will actually be a problem and will be so designated. A problem need not necessarily be difficult, but it must be of wide applicability and its nature must be such that solutions or discussions will make interesting reading.

Each month, a problem will be published, together with an offer of a $5 award for *every* solution or discussion subsequently printed.

Two months later, this problem and the solutions or discussions will be published; and five-dollar checks will be mailed to readers whose solutions or discussions are printed.

Thus, in our next issue (November) we shall publish Problem No. 1, and two months later (in the January issue) the Forum will be inaugurated with Problem No. 1 together with its prize-winning solutions and discussions. Problem No. 2 will appear in December and the second Forum discussion in February. And so on.

In one sense the two new departments will constitute an information exchange. In a more specific sense, however, they will constitute a perpetual data file. Classification numbers will be printed for your convenience.

Watch for these new features.

INSTRUMENTS' READERS AT WORK

No. 18—JOHN PETER MIKALOFF, JR.

Superintendent, Fuel and Steam Power Department,
Duquesne Works, Carnegie-Illinois Steel Co., Duquesne, Pa.

By M. F. BEHAR

IN the steel industry we have no "typical" subscriber. Some are electrical engineers who proudly show visitors their gleaming control boards and spotless calibration laboratories; some specialize in hydraulic control systems that operate huge valves more easily than a housewife adjusting a kitchen range burner; some do metallurgical work and have all their instruments within arm's reach, while others have charge of instruments scattered over square miles of clanging, clanking plants. Mikaloff's instruments are scattered vertically as well as horizontally: he and your reporter had to take an elevator to get within sight of the induced-draft fan controls on an upper platform of a skyscraping boiler house, as well as an automobile to look over controllers and recorders in remote departments.

This alone gives you an idea of the nature of his job, and the summarized list of his instruments conveys some idea of its importance. We should say "of his old job," for he was recently promoted to Superintendent of his Department, whose functions (stated briefly from memory) are:

Operation and maintenance of boiler houses;

Checking all combustion work, both in power plant and steel plant;

Charge of all instruments, meters and automatic-control systems (except those pertaining to electrical engineering and building maintenance, or to metallurgical research);

All pyrometric work;

Special engineering tests and field analyses in plant;

Checking production and distribution of steam, water, air and gas, and analyzing charts and figures;

Working on technical problems involved in steam generation, water treatment, plant lubrication, etc.

These functions are not suggested by the name of the Department. And while on the subject of names, it is not amiss to mention that Mikaloff's, too, is misleading. Not only was he born in Duquesne (1892), but his male ancestry is Swedish and—several generations back—Dutch; and his mother was a Pennsylvanian of English ancestry.

After graduation from the Duquesne High School, Mikaloff studied engineering at Penn State, where he took his B.S. in E.E. in 1915. In 1917, after two years of varied electrical work (mostly in Philadelphia) he enlisted in the Navy, was commissioned Ensign and served in Naval Engineering. Early in 1919, on being relieved from active service, he returned to his native town and started as an engineer in the Department which he now heads. (At that time, the Department was smaller in scope of functions, the boiler houses not being in its charge until 1931.) In 1924 he became its Assistant Superintendent and, although he is intensely loyal to his Company and modestly refuses to take any credit for his own achievements, it is a fact that much of the modern instrumentation around the Duquesne Works was installed under his direction. He generously gives a good deal of credit to *Instruments*, which he has been reading since the first issue came out in 1928.

Driving back from Duquesne, your reporter was thinking that it had been a pleasure to meet this example of quiet, self-effacing competence (who always says "the Company" or "the Department", and never "I") and also that Mikaloff's modest reticence had made it difficult to introduce him to you adequately through the medium of this page.

SUMMARIZED LIST OF INSTRUMENTS
UNDER MIKALOFF'S DEPARTMENT

(Exclusive of electrical instrumentation and of Bourdon gages, thermometers, thermostats, etc., under other Departments)

Air meters	2
Anemometers	2
Ammeters:	
Portable indicating	3
Portable recording	1
Barometer, mercurial	1
Boiler meters, recording:	
Pressure and draft	6
Steam flow and draft	6
Steam flow	12
Temperature (multi-pen)	6
Combustion control systems:	
Boilers	30
Blast furnace stoves	24
Metallurgical furnaces	15
Heating furnaces	4
CO_2 hand Orsats	4
CO & H recorders	2
Draft gages (liquid types)	30
Engine indicators	6
Flowmeters:	
Steam distribution	12
Gas distribution	60
Gas meters, wet test	3
Liquid level recorders	4
Pressure gages, Bourdon	36
Pressure recorders	24
Pyrometers:	
Contact	6
Optical	3
Radiation	3
Thermoelectric, recording	16
Psychrometers	2
Tachometers:	
Portable indicating	5
Portable recording	1
Recording	13
Telemetering System	1
Thermometers:	
Indicating (approx.)	100
Recording	12
Time recorders	24
Time recorder (special)	1
Vacuum recorders	4
Venturi meters:	
Water	2
Gas	1
Voltmeters:	
Portable indicating	1
Portable recording	1
Wattmeter, portable recording	1

PYROMETRIC STANDARDIZATION LABORATORY

1 precision potentiometer, 3 laboratory potentiometer and bridge sets, standard resistors and decade box, 4 standard cells, bench furnace & accessories, standard lamp and accessories.

LUBRICATION LABORATORY

Centrifuge, flash and burning point tester, viscosimeter, etc.

BOILER WATER LABORATORY

Chemical control equipment.

HE MONTH'S NEW INSTRUMENTS

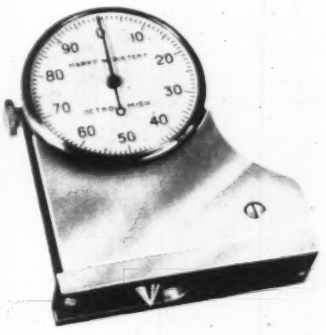
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Hardness Tester for Baked Cores and Sand Molds

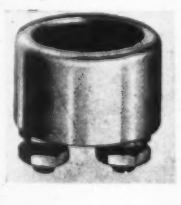
Weighing 12 oz. and being 3" long and ½" thick, this instrument may be carried in foundryman's pocket. It permits surface hardness of cores and dried sand



molds to be determined in a few seconds, by pressing it against the surface to be tested and drawing it along this surface —this procedure being similar to the "finger-nail scratch test" but resulting in a quantitative measurement of "penetration hardness," not "scratch hardness," since the dial measures the force along the axis of the diamond-cone-tipped spindle and not the force required to pull the diamond along the core surface. Maker supplies a table of hardness readings whereby the instrument may be used as a foundry standard.—*Harry W. Dietert Co., 6760 W. Grand Blvd., Detroit, Mich.*

High-sensitivity Selenium Cell

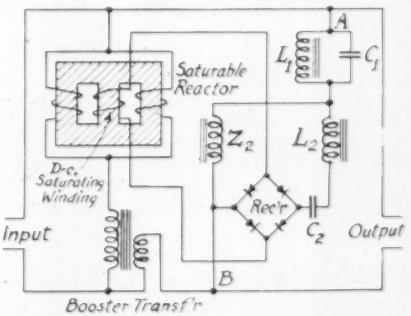
New "Type 50A2" is a high-resistance, high sensitivity selenium cell designed especially for commercial photoelectric control in conjunction with an amplifying tube and relay.

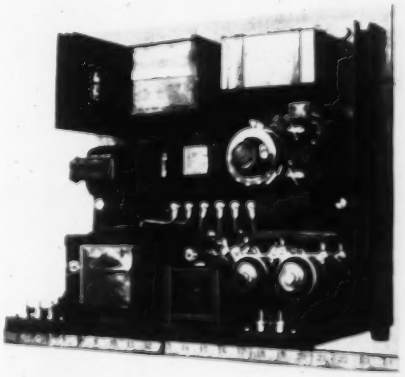


Active surface is elemental selenium on platinum electrodes, sensitized by activation treatment. It is said to possess great stability, dependability and long service life when used in correctly designed circuits. Due to peak sensitivity to deep red wavelengths, and inverse non-linear response to light intensity, it is particularly suitable for use with low-intensity and low-temperature light sources. Approx. dark resistance 10 megohms, minimum change at 10 foot-candles, 5:1; maximum d-c. or peak a-c. voltage 80 volts, normal (recommended for continuous duty) 50 volts; illumination for greatest stability in continuous operation, intensity <20 foot-candles. Max. operating ambient temperature 150° F. Overall diameter 0.770", overall length 0.75"; active area 5/16" × 5/16".—*Acousto-Lite Laboratories, 2930 S. Vermont Ave., Los Angeles, Calif.*

Booster Voltage Regulator

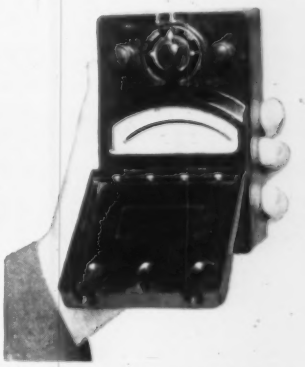
"Type REF" regulator has an efficiency of approx. 90% at half load (higher at full load), introduces no appreciable wave form distortion or displacement, is provided with two main adjustments: By means of one, regulation point may be changed in 2-volt divisions; by means of the other, accuracy of regulation may be altered. It employs no moving parts, consisting essentially of a voltage-sensitive network, a saturable-core reactor and a booster transformer. Parallel and series resonant circuits (L_1C_1 and L_2C_2 in simplified diagram) are employed, with characteristics such that upon decreasing input voltage, the rectified current flowing through the saturating winding is increased, decreasing the reactor's impedance and thereby impressing more voltage on the booster transformer which consequently adds more boost to the line. Photograph shows the 2½-kva. unit; others are available for 5-kva. and 7½-kva. loads. All are single-phase, obtainable in either 120-volt or 240-volt types, and normally designed for 10% maximum boost.—*Roller-Smith Co., 2132 Woolworth Bldg., New York City.*





Light-weight Pocket-size Electrical Instruments

A complete new line of pocket-size voltmeters, ammeters, and milliammeters, designated "Type AS-5" and superseding "Type AS-3," is characterized by



higher torque and improved characteristics. Over-all dimensions of standard unit are 5½" × 3½" × 2", and weight is 12 oz. Accuracy is 1% of full-scale value. Instruments have magnetic damping, a Permaloy moving vane, and are shielded from stray magnetic fields. All have the combination of knife-edge pointer and mirror scale which eliminates parallax error. On the double- and triple-scale instruments, a convenient switch on the face makes it possible to change ratings without removing or rewiring terminal connections. The case is of Textolite.—*General Electric Co., Schenectady, N. Y.*

Synchroscope for Aircraft Engines

In multi-engine aircraft it has been found that lack of synchronism produces beat noises which disturb all passengers and frighten some, and may produce vibrations injurious to the aircraft structure and equipment. To permit close adjustments of engine speeds there has been developed a relatively simple synchroscope, applicable to two or more engines (of the spark-ignition type) and requiring no additional electrical or mechanical connections between engines and instrument panel: it is connected by light gage wire to the engine magneto switches. No scale appears on the dial, approach to synchronism being indicated by slowness of pointer oscillations. A selector switch is provided for applications involving three or more engines, in which case one engine is chosen as "master" and the others successively synchronized therewith. Instrument is designed for 1⅞" SAE flange, weighs 10 oz., draws 0.1 milliamp. from each magneto primary.—*Eclipse Aviation Corp., East Orange, N. J.*

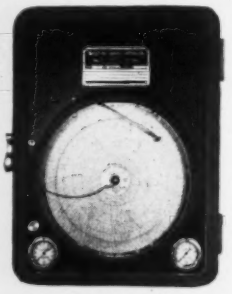
BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.



Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

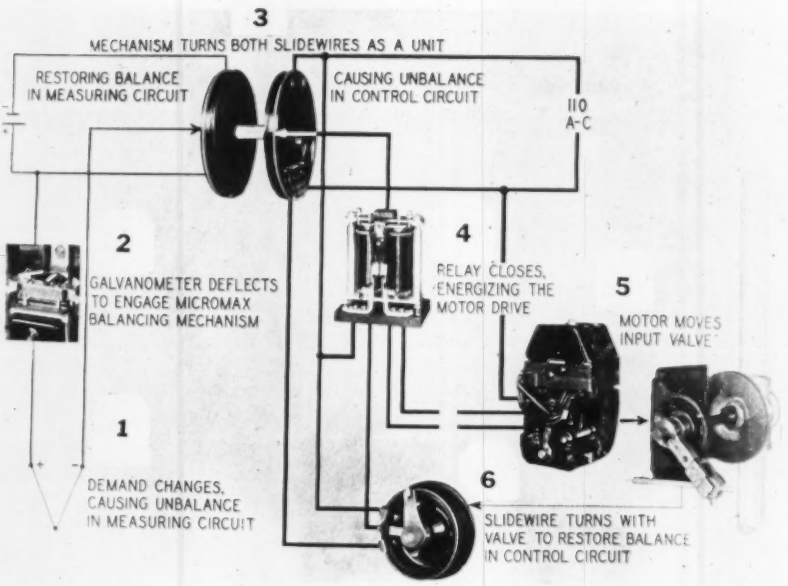


Fig. 1

Universal Electrical Automatic-control System

In this new system the control instrument proper is a "Micromax" unit (of any of the types reported in these columns since 1932) but the relay detector unit and the valve-drive unit have both been developed and engineered to work with the instrument. Entire system, therefore, operates as a unit at full sensitivity of Micromax instrument, and at desired extent of its available accuracy and speed. For example, one application is the control of a motor-generator set (of low inherent time-keeping accuracy), using a frequency standard (such as an L&N dynamic type tuning fork) whereby the m-g. set can serve as a secondary-standard frequency source (maximum differential 0.2 second). Coördination of all elements is made evident in Fig. 1 which represents a temperature control

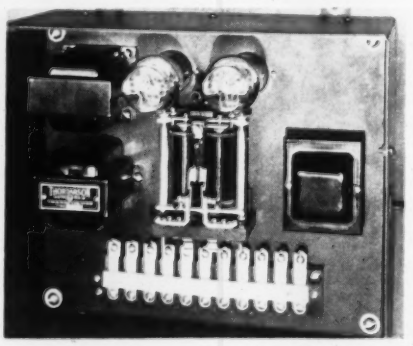


Fig. 2

set-up with a thermocouple as primary condition-sensitive device and a fuel valve as final device under command; and which brings out also the coupling of the measuring and control circuit. Not shown are the following three elements: (1) a control setter of conventional knob form; (2) a throttling range setter for determining the width of the control band equivalent to full valve travel; (3) a droop corrector—manual or fully automatic—for shifting control band up or down with respect to main scale in the event of a sustained change in demand. Principal overall characteristic of Micromax Electric Control, therefore, is the proportioning of input to demand.

Fig. 2 shows new relay unit, said to be so vibration-proof that accidental operation is virtually impossible. Ample sensitivity is obtained by use of two electron tubes which amplify bridge unbalance.

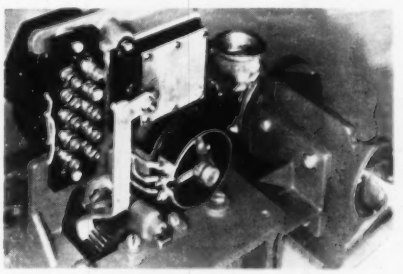
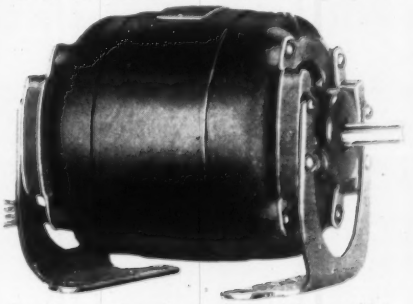


Fig. 3

Fig. 3 shows new valve drive unit, comprising a reversible motor, a gear train, a control slide-wire and a pair of limit switches. Linkage between motor drive and valve may be adjusted easily, so that when desired, valve may be moved an extent smaller than from full-open to full-closed.—*Leeds & Northrup Co., 7500 Stenton Ave., Philadelphia, Pa.*

Resilient Mounting Base

A new resilient mounting base for fractional horsepower motors is said to give the utmost in quietness and freedom from vibration, the motor being carried



by live rubber in shear, which is said to be a much more efficient absorber of vibration than rubber in compression or tension. Despite its high resilience, the mounting is said to be "unusually stable."—*Bodine Electric Co., 2254 W. Ohio St., Chicago, Ill.*

Sound Level Meter

Designed to meet the demand for an inexpensive sound level meter complying with the tentative standards of the ASA, AIEE and Acoustical Society of America, this instrument incorporates several features said to be previously found only in more expensive and cumbersome instruments and is suitable for practically all types of commercial sound level measurements. Among its features are: (1) A non-directional crystal microphone which responds satisfactorily over a range of frequencies, including the high frequencies which make up "hissing" and "swishing" sounds; (2) Sensitivity extending to 24 db above a zero reference level of 10^{-16} watts/cm.^{2}; (3) Three separate weighting networks for adjusting frequency response characteristics: a low-level network, a high-level network, and a network giving a substantially flat over-all response; (4) no rheostats or other battery adjustments; (5) Unusually light weight, 23½ lbs. with batteries; dimensions 11½" × 13½" × 9½"; (6) Tube suspension providing freedom from microphonic noises; (7) No inductance coils or transformers used in instrument, thus eliminating error due to magnetic pickup.—*General Radio Co., 30 State St., Cambridge A, Mass.*

Pocket Volt-Ohm-Milliammeter

"Ranger-Examiner Model 735" is a pocket-size volt-ohm-milliammeter with selector switch and d-c. ranges comparable to those of larger multimeters: 15-150-750 volts; 1.5-15-150 milliamperes; ½-1000 low ohms; 0-100,000 high ohms at 1.5 volts. External batteries may be used for higher resistance measurements. Indicating instrument is Triplett d'Arsonval type. Readings are said to be accurate within 2%. Molded case, with rounded corners and silver-and-black panel, is 3 1/16" × 5⅞" × 2¼". "Model 735" is furnished complete with battery and test leads with alligator clips.—*The Readrite Meter Works, Bluffton, Ohio.*

Edgewise Draft, Pressure and Temperature Instruments

A new line of boiler instruments is announced, all in 12" × 12" × 2¾" cases permitting user to make up any combination meeting his requirements, and to change units at any time, each unit being easily removable without disturbing others. Fig. 1 shows a four-unit arrangement consisting of (left to right) furnace draft gage, boiler draft gage, wind box pressure gage and flue-gas thermometer. Draft and pressure elements are new. Fig. 2 shows a draft gage with its left-hand side plate removed. The newly designed slide petcock is mounted into the bottom of the case and the left-hand lever can be used to shut off the draft and vent the gage, thus allowing pointer to come to zero, the right-hand bottom lever then being used to adjust for zero. Diaphragm element is suspended on two "needle-point bearings." In the pressure gages the bottom plate carrying the diaphragm is reversed. In the thermometer units a gas-filled tube-system is employed.—*Defender Automatic Regulator Co., St. Louis, Mo.*

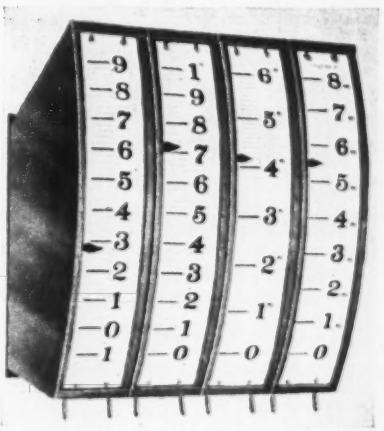


Fig. 1

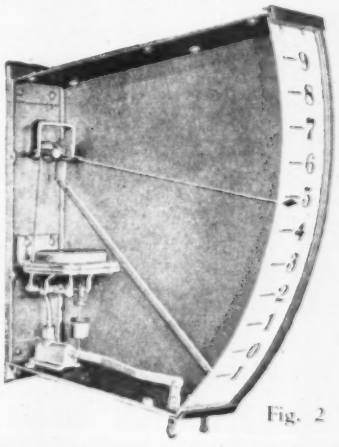
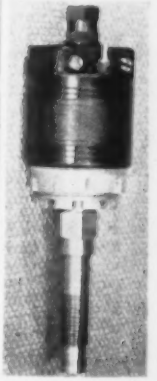


Fig. 2

The Type III Pressure Element for the Research Direct Pressure Engine Indicator



This new Pressure Element has the highest speed and the most exact timing of any sampling valve type of pressure element. It is a vital part of the Direct Pressure Engine Indicator and is the result of years of research in this particular field.

The following instruments are offered:

Air Flow Indicators of the Variable-Venturi, and Smooth Approach Orifice types.

Engine Indicators including the Research Direct Pressure Engine Indicator (made by us) and the Piezo-Ray Pressure Indicator (made for us by the RCA Mfg. Co.).

Fuel Flow Indicators including the Research Direct Reading Fuel Flow Indicators, Jet Comparators (for production inspection of jets) and the Rotameter (Schutte and Koerting).

Magnetic Thickness Gauges for measuring cylinder walls by contact with the inside wall only. A new unit now available for bores as small as 2⅛ inches.

Slow Motion Study Equipment including the Strobotac and the Edgerton Stroboscope (General Radio Co.).

Sound Study Equipment including the No. 556 Noise Meter (General Radio Co.).

Vibration Study Equipment including the Geiger Torsiograph (imported) the Vibrometer (Electrocon Corp.), and the Cathode Ray Oscillograph (RCA Mfg. Co.).

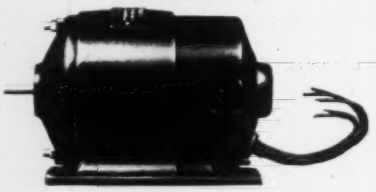
You are cordially invited to visit our laboratory. Many of the instruments listed can be seen in operation.

Detailed information mailed on request.

Commercial Engineering Laboratories

4612 Woodward Avenue, Detroit, Mich.

New!



AUTOSYN
SELF-SYNCHRONIZING
MOTOR
TYPE I

Type I Autosyn motor is a reasonably priced self-synchronizing motor with superior performance characteristics. One transmitter may operate as many as six receivers. Practically any system of remote indication or control may be solved by the selection of the proper type of Autosyn Motors.

FEATURES

1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
2. Approximate accuracy: Two degrees.
3. Maximum torque 14.8 inch ounces.
4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3⅝"x39/16"x 5¾".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

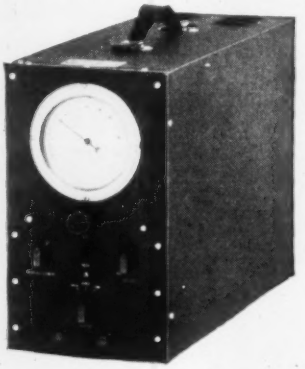
COMPLETE INFORMATION ON REQUEST

BENDIX MARINE PRODUCTS CO., Inc.

Subsidiary of
Bendix Aviation Corporation
754 Lexington Avenue
Brooklyn, N. Y.

Audio Oscillator

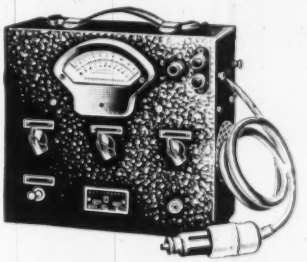
Portable (31 lbs.), a-c. operated (110-120 v., 60-cycle) and provided with a reed whereby main-scale calibration may be relied on within 2%, this new beat



frequency audio oscillator is calibrated from 10 to 20,000 cycles. Two output circuits are provided, one for loads >10,000 ohms, and one for loads >500 ohms. High impedance output is resistance-capacity coupled to output tube and has a maximum open circuit output voltage of 30 volts. Low impedance output is supplied through a special transformer in which the d-c. component of plate current has been balanced out. Open circuit voltage is approx. 10 volts maximum and with a 500-ohm load this drops to about 8 volts, giving a power output of 0.12 watt. Output control is provided on panel. At frequencies >100 cycles, total harmonics are <5% of the fundamental. Total ripple and r-f. <0.6% maximum output voltage.—*United Sound Engineering Co., 1231 University Ave., St. Paul, Minn.*

Combination Vacuum-tube and Peak Voltmeter

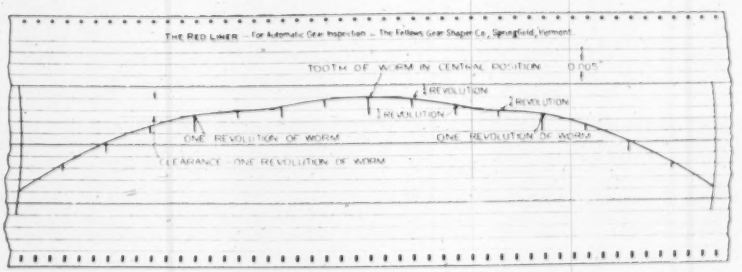
For measuring potential in radio and audio frequency circuits, as well as in circuits where even the current drain of high resistance moving-coil instruments introduces distortion, "Model 88" combination vacuum-tube voltmeter and peak voltage indicator comprises a vacuum-tube voltmeter of "extremely high sensitivity" and input resistance of 10 megohms, plus a peak voltmeter of the slide-back type operating from a self-contained power supply. As a vacuum-tube voltmeter, a range of 0-1.2 volts rms. is covered by direct connection to

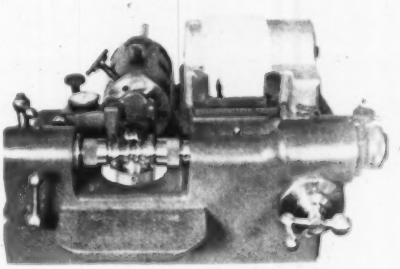


the tube (Type 6F5 metal) grid without any shunts. The voltmeter tube is placed at the end of a 30" extension cable, making possible direct connection of the tube grid-cap in the measured circuit, and thus eliminate capacity effects. For work in lower frequency circuits, the tube may be placed in the instrument case and connections made through front panel binding posts. As a peak voltmeter, ranges of 0-10 and 0-100 are provided without need of external power supply. Entire unit is housed in a metal carrying case finished with baked black crystalac enamel. Fan-type jeweled-bearing indicator has a green molded case.—*Clough-Brengle Co., 2815 W. 19th St., Chicago, Ill.*

Worm Clearance Recorder

Specially adapted for the autographic inspection of hourglass steering worms, this newest addition to maker's gear-checking recorders differs from the others (which are fully automatic) in that it is purposely designed for hand operation. The records, however, are of the same general character, each being a magnified curve of the clearance which the instrument has been set to measure, with jogs at predetermined angular intervals, this curve being traced on a strip chart which travels in proportion to the rotation of the worm being inspected, the abscissa thus representing angular distance and the ordinates representing clearance magnified 40× (50× in the case of instruments recording in Metric measure). The trace is made with a recording pen supplied with red ink, whence the designation "Red Liner"

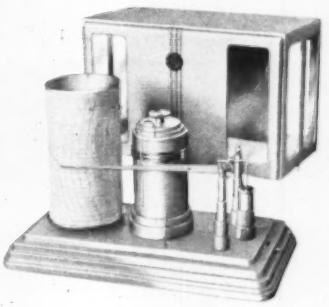

THE RED LINER — For Automatic Gear Inspection — The Fellows Gear Shaper Co., Springfield, Vermont
TOOTH OF WORM IN CENTRAL POSITION
0.005"
1 REVOLUTION
1 REVOLUTION
2 REVOLUTION
ONE REVOLUTION OF WORM
ONE REVOLUTION OF WORM
CLEARANCE - ONE REVOLUTION OF WORM



for autographic gear inspectors of this make. Max. capacity of new instrument is 3" pitch diam.—*The Fellows Gear Shaper Co., Springfield, Vt.*

Barographs

... new drum-chart, dry type (aneroid recording barometers are announced, both embodying recent refinements in the way of temperature compensation, seasoned seamless pressure chambers, jeweled 8-day clock movements, fine-line pens using special ink,



etc.: (1) *Microbarograph* (illustrated), available in six models for elevations from sea-level to 3000 ft., each having a range of 2.5" mercury column (approx. 500 ft. atmospheric column). Chart width being 6¼", scale of ordinates represents a 2½× magnification over mercurial type. Outside dimensions approx. 6 × 9 × 12", weight 11½ lbs. (2) *Station Barograph* available in six models for elevations from sea-level to 6000 ft., each having a range of 3" mercury column and a 4½" wide chart; differs also from microbarograph in that cover is all-glass. —*Julien P. Friez & Sons, Inc., Baltimore St. & Central Ave., Baltimore, Md.*

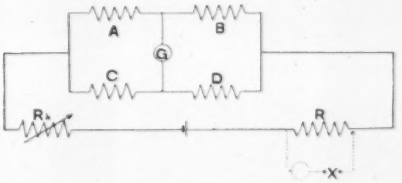
Hand Fan Psychrometer

"Genware" ventilated psychrometer weighs 3½ lbs. with all accessories as illustrated (2 lbs. without belt, body plates and bracket), this minimization of weight having been accomplished by reducing the ventilating means to a hand-driven fan in which an aluminum disk is in frictional engagement with a fibre

collar on the fan-wheel shaft. Wooden base is 7" × 8" and overall height 14¼". Etched-stem thermometers, 9½" long, are regularly supplied in —20° to 120°F. range with 1° divisions or 0° to 100°F. in 0.5° divisions. Other ranges (F. or C.) can be supplied. Each psychrometer is supplied with a humidity chart embodying corrections for altitude above sea-level, and with filing cards on which observations may be entered. Model illustrated is designed for use in locations too small or too crowded for use of conventional sling psychrometer. It and the beltless model are designed also for use by observers desiring to take readings while wet-bulb and dry-bulb are being ventilated.—*G.M. Mfg. Co., P. O. Box 151, Madison Sq. Station, New York City.*

Portable Potentiometer

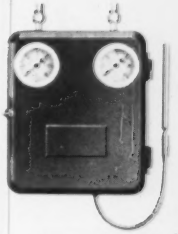
Circuit: In place of a cadmium-cell reference standard of e.m.f., this portable instrument, known as "Model C" potentiometer, employs a modified Howell bridge *A B C D* with linear and non-linear coefficient arms so proportioned that galvanometer *G* indicates balance at only one value of current flowing through these respective arms, thereby providing a current standard. This establishes a known potential drop along calibrated potentiometer slide-wire *R*, which is in series with the current standard. The



bridge having been balanced, the same galvanometer *G* is then switched over into the potentiometer circuit as shown by the dotted lines. *Construction*: Instrument measures approx. 6" × 7" × 4" overall, weighs approx. 4 lbs., has bronze handle instead of leather strap. Slide-wire scale, approx. 15" long, mounted on slide-wire form, is individually calibrated to read directly in units for which each instrument is to measure. The constants

of the current-standard bridge are likewise selected for each individual instrument with regard to its intended use. For example, if instrument is to be used with a certain type of thermocouples, bridge-arm characteristics are so selected that cold-junction error is automatically compensated. Non-linear resistors are of tungsten-wire-in-vacuum type. Values and characteristics are such that clumsy use of current-adjusting rheostat *Rh*, or even full unbalanced current when *X* is disconnected, cannot impair calibration of current standard, and instrument is said to be fool-proof. Ordinary flash-light dry cells make up the d-c. source. Single-range form of instrument is available in seven models, for use as millivoltmeter or with various thermocouples, pH cells, etc. A double-range form also is available from stock, reading 0-16 and 16-71 millivolts.—*Hurl R. Adams, Alhambra Way, Pittsburgh, Pa.*

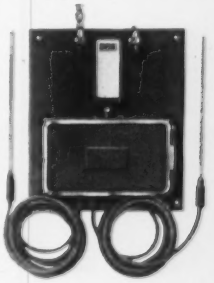
ACCURATE CONTROL at Remote Points!



JOHNSON EXTENDED TUBE THERMOSTATS

● For use where it is not convenient and possible to place the controlling mechanism and the sensing element at the same location, Johnson thermostats with mercury-tube transmission between bulb and instrument are dependable and accurate devices. Bulbs for every requirement between 40 degrees and 1000 degrees Fahr. Capillary tubing up to 75 feet long, protected by bronze braiding and armor.

● Johnson wet-bulb attachments in various forms convert these devices into superior wet-bulb controllers.



JOHNSON DIFFERENTIAL THERMOSTAT

● An extended tube thermostat with two sensitive elements to operate automatically according to the relationship between the temperatures at two different points. The ratio of the change in pilot temperature to the change in controlled temperature is adjustable between 4 to 1 and 1 to 4.

● Send for literature or call our nearest branch office. Bulletin T-303 describes the Extended Tube Thermostat and the various bulbs for all instruments. T-304 covers the Differential Thermostat. H-310 shows Wet-Bulb attachments and includes Humidity Tables from 20 to 198 degrees.

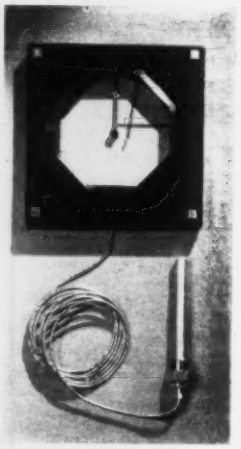
JOHNSON Temperature CONTROL

JOHNSON SERVICE COMPANY
Main Office and Factory: MILWAUKEE, WIS.
Branch Offices in all Principal Cities

REPUBLIC RECORDING THERMOMETER

featuring a

"Cartridge Sealed" Helical Element



The New Republic Recording Thermometer (gas-filled type) introduces a helical element which is completely enclosed in a metal cartridge as a protection against dirt, moisture or damage by handling. The helical coil, capillary tubing and sensitive bulb are filled with nitrogen gas, calibrated and sealed, in the laboratory, to form a complete thermal unit.

•

This complete unit can be easily and quickly removed for recalibration, repair or change of temperature range, without disturbing or exposing any mechanism in the reading instrument.

•

Sensitivity, accuracy and trouble-free performance were stressed in this new design of thermometer, which fulfills all the requirements of modern industrial use.

•

The reading instrument may be placed at any distance, up to 200 feet, from the point of temperature measurement.

•

Evenly divided charts permit uniform closeness of readings throughout the entire range.

•

Combination records of temperature, flow, CO_2, draft, pressure, etc., may be obtained with multiple recorders.

Data Book 210, just published, gives complete description.

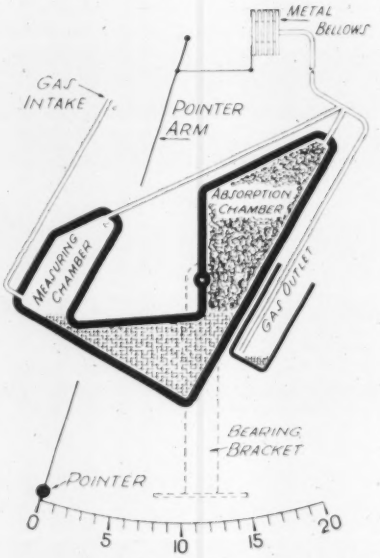
Mailed on Request

REPUBLIC FLOW METERS CO.

2249 Diversey Parkway, Chicago, Ill.

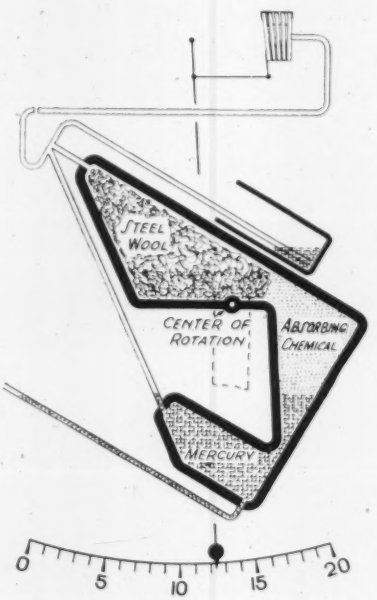
Portable Automatic CO Analyzer

An entirely new type of flue-gas analysis instrument makes its appearance in the form of the "Orsatomat" which belongs in the classification "hand



TAKE SAMPLE
POSITION No. 1

Orsat" by reason of its principle, portability and price, but requires no manipulation (other than moving one lever) and indicates by pointer movement on a scale, the analysis being accomplished automatically in 20 seconds, so that its characteristics are akin to those of the



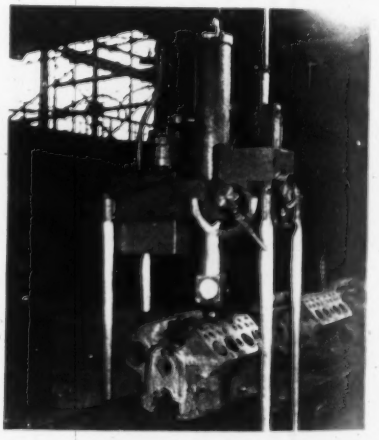
TAKE READING
POSITION No. 2

"panel-board" classification. The simplified diagrams will make the operating principle evident to *Instrument* readers without further explanation, and the photograph shows (in front of handle) the knob-tipped rod which is pulled up for taking sample and then pushed in to cause sample to be automatically analyzed. The Orsatomat is available in the standard model illustrated for O_2 (which includes a draft gage and provides space for a flue-gas thermometer) also in a twin unit model for analyzing

for both CO_2 and O_2. Models with special scales are offered for use in testing automobile exhaust gases. — *Hays Corporation, Michigan City, Ind.*

Direct-reading Conveyor Brinell Machine

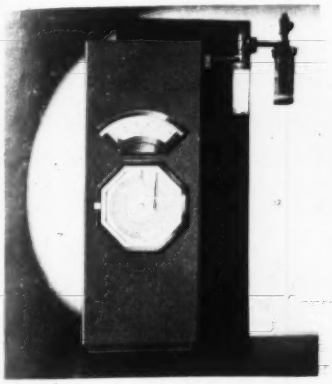
This machine has been developed for testing cylinder blocks, cylinder heads, die blocks, etc., on a conveyor without elevating them to the testing position. The ram, which is the moving member, with a travel of 24", is operated in the same manner as that of a steam hammer and may be held at a height to accommodate the size of blocks on production. Conveyor section is spring mounted, which permits blocks to rest on a solid support when load is applied. Direct-reading device is the same as in makers' Standard Brinell Power Machines. Tests can be



made without grinding or spotting or using a microscope: after tolerance hands are set to the desired limits, the operator merely notes that the indicator pointer stops within them. Since the actual test made is the Brinell, the accuracy of indication may be checked with a microscope. Oil is used as the pressure medium, assuring thorough lubrication and long life. To avoid viscosity changes this oil is kept at a constant temperature with a thermostatically controlled heating element. Work-gap between platens is 24" × 31". — *Detroit Testing Machine Co., 5137 Trumbull Ave., Detroit, Mich.*

Recorders and Indicators

A complete line of CO_2 recorders, indicating recorders and electric remote-reading systems is announced. Illustration shows "Type MDI" in which an in-



dicating dial permits reading from a distance. In all models, the percent CO_2 in the flue gas is measured by the Orsat method, a continuous sample being drawn, cleaned, cooled, and successive volumes thereof analyzed volumetrically. The meter is driven by a fractional horsepower electric motor and requires no water for its operation. There is no possibility of stoppage in the gas line as the instrument has a suction capable of drawing 14" of mercury. The caustic tank holds enough potash to last from four to six months. All analyzer parts being in tank assembly, temperature variations have no effect on the readings. A filter in the gas line removes all SO_2 from the flue gas before it reaches the analyzer. A continuous pen line record is inscribed which may be read directly in percent CO_2 and related factors, such as steam flow, temperature, draft, pressure, etc., may be combined on one 10" round chart; and various edgewise indicators as well as flow integrators added to the recorder on the standard 40" high and 16" wide 12-gage steel panel.—*Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.*

Radio Analyzer

Trade name "Roto-Ranger" is descriptive of outstanding novel feature of this new multimeter—its roto-dial mechanism, so designed that when the selector switch is moved to any one of its twelve positions, the proper scale comes into view. In other words, the selector knob (at right on panel) switches the circuit and dial simultaneously, minimizing the possibility of error in reading, because (a) only one scale to read and (b) no necessity for multiplying or dividing indication. Use of independent scales, it is said,

has made it possible "to give each scale a practical, workable range suited to the job at hand." Available ranges:

0-8-130-1000 a-c. volts
0-8-300-1000 d-c. volts
0-1.8-130 d-c. milliamps.
0-100 ohms (mid-scale 5)
0-50,000 ohms (mid-scale 1400)
0.2 megohms (mid-scale 21,000)

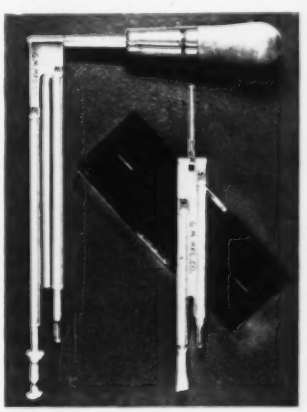
New analyzer is adapted for measurement of current, voltage, and resistance from receiver sockets through the cord and plug, or "point to point" method employing test prods.—*Simpson Electric Co., 5216 W. Kinzie St., Chicago, Ill.*

Hydrometer

Known as "Permax" (permanent accuracy, maximum visibility) this new hydrometer is said to be different "not in just one superficial detail, but in three outstanding innovations." (1) Most obvious change is in appearance: streamlining permits it to sink more rapidly to the floating point and prevents formation of air bubbles when used in "very viscous liquids." (2) Scale is of enameled, lightweight metal and is fused into the alloy weighting material; all of which will stand 300° F. without discoloring or loosening. (3) Flat scale with graduations and figures on both sides is said to give at least three times the angle of vision obtainable with the regular paper scale type of instrument.—*Taylor Instrument Companies, Rochester, N. Y.*

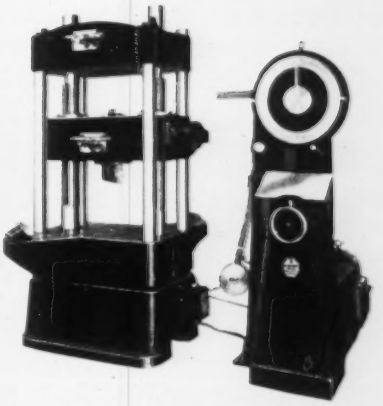
Sling Psychrometers

Two new sling psychrometers are announced: "No. 3101" (left) has 9½" thermometers, both in —20° to 120° F. range with 1° divisions, or both in 0° to 100° F. range with 0.5° divisions. Other ranges can be supplied. Metal parts are of Monel metal. "No. 3105" pocket model (right) has a swivel handle folding between thermometers; these are 5½" long



and regularly supplied in 0° to 100° F. range. Snap-lock case permits carrying this instrument in coat pocket. Both psychrometers are supplied complete with extra wick, humidity chart and instructions.—*G.M. Mfg. Co., P. O. Box 151, Madison Sq. Station, New York City.*

ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS



RELIABILITY

Day in and day out, whether the coldest winter day or hottest summer day, Riehle Precision Hydraulic Testing Machines give true readings. The dead-weight automatic indicating system has no springs, no levers. Results are positively accurate. And, *no recalibrations are necessary.*

Today, as for more than a century and a quarter, Riehle Machines are preferred in government departments, steel companies, educational institutions and industrial research laboratories. Write — ask for descriptive bulletins.

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AMERICAN MACHINE AND METALS MANUFACTURING CORP.

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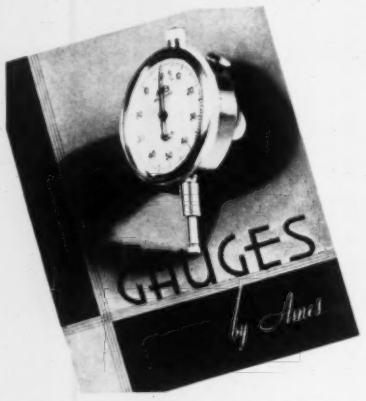

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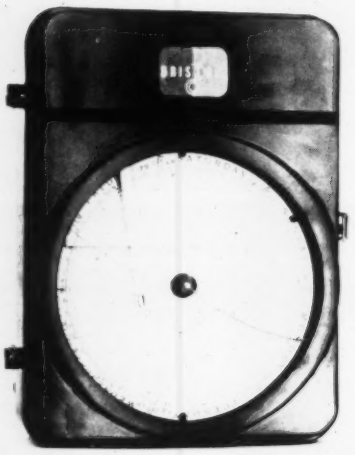
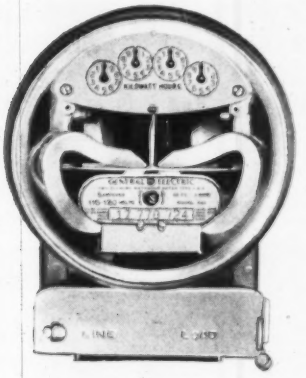


Round-chart Recording Voltmeters and Ammeters

A new line of round-chart recording voltmeters and ammeters has been developed to take care of the requirements of electric utilities for instruments easy to use and service, and of industrial plants—especially for process work where voltage and current affect the quality and production cost of the product. Models are available for wall, switchboard, flush panel, and pole mounting, and for portable use. Instruments are housed in a moisture-, fume-, and dust-proof case made of an aluminum alloy. Measuring elements can be easily replaced by removing three screws from the mounting. Pen-arm is pivoted at top in such a way that pen pressure against chart is controlled by gravity. This is said to eliminate possibility of sluggishness due to pen-arm becoming bent. Pen-arm is equipped with micrometer zero adjustment and with chromium-plated tip which may be removed by loosening one screw. Two-drop fine-bore platinum-point fountain pens, especially developed for these instruments, are said to make legible records even when values fluctuate widely. Recorders are offered with spring-driven or electric Telechron clocks.—*The Bristol Co., Waterbury, Conn.*

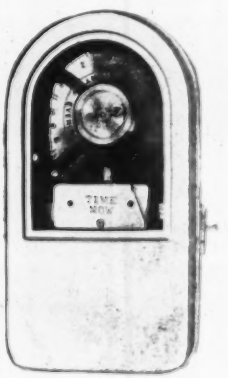
Two-element Single-Disk Watthour Meter

Comparable in size and weight with single-element meters, a new two-element single-disk watthour meter is available in two forms, "V-2A" for wall or connection-box mounting, and "V-2S" for socket mounting. The necessary freedom from interference between elements has been obtained through the use of a new type of rotating element. This new disk is composed of five laminations (each having five radial slots) assembled with insulation between them and with the slots staggered. This construction confines the eddy currents in the disk to the vicinity of the electric element producing them. The meter is said to be compensated for all classes of temperature errors and accurate to 300% of normal load current at both unity and one-half power factor.—*General Electric Co., Schenectady, N. Y.*



24-hr. Time Switch

For daily automatic control of electrical circuits, new Little Giant Tork Clock operates without winding or regulating and may be quickly set on variable schedules without use of tools. Simplicity in design is claimed to effect a quick make and break action with pure silver contacts with nearly 50% less parts than formerly used. The 24-hr. day is divided into four sections of six hours each. Entire device is made of non-corrosive materials; gears run in sealed oil chamber; rifled bearings and a new centrifugal thrower prevent oil leakage. A counter-clockwise second hand indicates proper motor operation. Device has 5,000-watt capacity for either single or double-pole service, is housed in a cadmium-plated case with unbreakable window, weighs 3 lbs.—*Tork Clock Co., Mount Vernon, N. Y.*



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INSTRUMENTS' SYMPOSIUM ON MEASUREMENT OF RIDING COMFORT

(In cooperation with Riding Comfort Committee
Society of Automotive Engineers)

The New NBS Ridemeter

By H. C. DICKINSON

Chief, Heat and Power Division, National Bureau of Standards

A SATISFACTORY ridemeter should not only indicate the momentary amount of discomfort or roughness, as experienced by a passenger in a car, but should also be capable of integrating the roughness over any desired interval. To be practically usable, it should present each result as a single number rather than in such form as wiggles on a tape, requiring arduous labor to interpret, if interpretation be possible.

A new ridemeter, basically similar to the earlier one described in the November 1935 *Instruments*, consists of a pneumatic cushion connected through an anemometer to a fixed volume. The anemometer is of the hot-wire type, the circuit diagram of which is given on the figure herewith. A dry cell supplies the operating current, about $\frac{1}{4}$ ampere being required. Current is regulated by a 30-ohm variable resistor. The bridge, consisting of two hot wires in the anemometer tube and two similar wires in a sealed tube, is balanced by a $\frac{3}{4}$ ohm variable resistor in series plus a 30-ohm resistor in parallel used as a vernier.

The measuring circuit across the bridge includes a double-pole, double-throw switch. In one position the microammeter and parallel shunt are connected to the ampere-hour meter; in the other position the shunt and ampere-hour meter are disconnected, only the microammeter being in the circuit.

A variable shunt (left) is connected in parallel with the measuring circuit, to vary the sensitivity of the apparatus. Each step alters the reading of the microammeter by a factor of 2, the total variation being by a factor of about 64. Since including the ampere-hour meter reduces the sensitivity by a factor of about 50, the total range in sensitivity is about 3200 to 1, or the smallest deflection which can be observed on the milliammeter is about one millionth part of the maximum capacity of the instrument.

The principal difference between this and the instrument described earlier, in addition to greatly increased sensitivity, is the substitution of an electrical for a mechanical integrator of the total air flow. The apparatus is so designed that the sensitivity of the integrating element can be varied in six equal steps by a factor of 2^6, and that of the indicating element can be varied similarly by a factor of 2^{12}.

In the course of several hundred miles of road tests, it has been found that the results obtained at different speeds and on different kind of roads can be brought increasingly into accord with the conclusions of riders by properly regulating the capacity of the air reservoir. This has been varied between one gallon and one pint.

A variable speed and variable amplitude oscillating seat has been built on which to calibrate the pneumatic cushion ridemeter for different types of accurately measured oscillations over the range of frequencies and amplitudes which are important. This will permit adjusting the relative sensitivity under different conditions to correspond with the average sensitivity of persons.

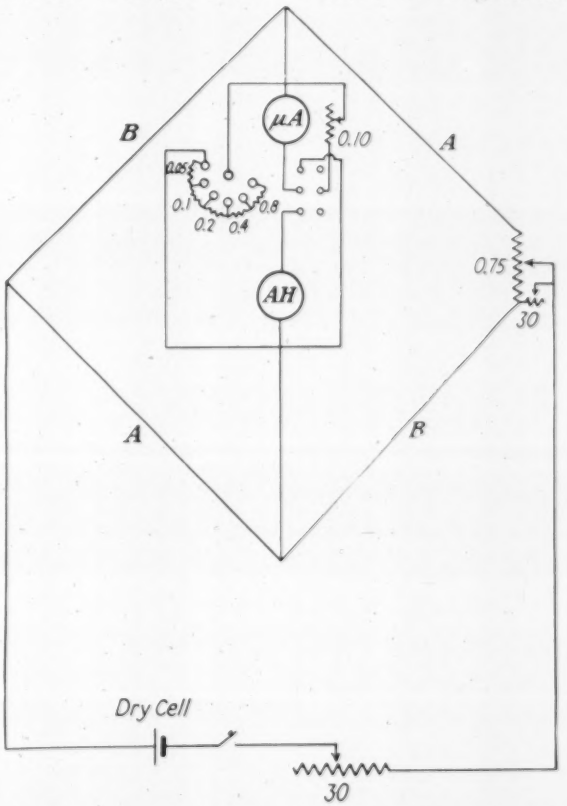


Fig. 1. Circuit diagram of NBS Ridemeter. AA—hot wires used in Anemometer. BB—compensating wires in sealed tube. Numbers are values of resistance in ohms.

A Practical Riding Comfort Meter

By ROY W. BROWN

Charge, Engineering Research, Firestone Tire & Rubber Co., Akron, Ohio
Chairman, Riding Comfort Research Committee, S. A. E.

RECENTLY, the Riding Comfort Research Committee of the Society of Automotive Engineers has been concentrating development efforts along the lines of reducing formerly available laboratory type research instruments into simple, rugged, practical devices of everyday value to the engineer in making routine measurements of riding comfort. Its "ten-point" specifications for such instruments were published in these columns last November.[1]

Some years ago, after numerous attempts, the Firestone laboratories succeeded in producing an accurate contact type accelerometer[2,3] operating on the solenoid principle. This instrument has undergone further development described below and is now believed to meet requirements of practical riding comfort measurement.

A number of the original design instruments have been made and used by various organizations. Thousands of miles of road service under such severe conditions as occur on truck axles with worn solid tires have positively substantiated the soundness of the actuating element.

Experience with numerous spring-supported weights arranged so that accelerations overcome the spring tension and cause contacts to open indicated that some means must be used to eliminate the contact chatter which invariably occurred by reason of the natural frequencies in the various parts of the assembly. The inherently unstable characteristics of the movement of the core in an iron clad solenoid led to the adoption of the type accelerometer element[4] illustrated in Fig. 1.

This construction has been thoroughly investigated and not only found to meet scientific requirements[5] but to be practical in measuring the exceedingly brief maximum accelerations of motor vehicle axles.

To record maximum accelerations which occur in such short time intervals, possibly only several thousandths of a second, necessitates an extremely rapid registering or recording device. Sensitivity of the device must also be high as the amount of current which can be passed through the contacts is limited, otherwise deterioration of the contact with resultant change in calibration will occur. Numerous devices were investigated, among them the electrolytic type of integrator.

A high sensitivity counter was finally developed[4] in which fast operation with low energy input was realized at the expense of ruggedness and simplicity. Usable results could be secured if skilled attention and usage of the device were provided. This requirement placed the instrument definitely in the laboratory rather than the practical class.

An investigation was made to determine if commercially available instruments would meet the requirements of high sensitivity, high speed and non-inductive circuits. Since the electrical contacts function also as mechanical stops, it is important that their physical dimensions remain precisely constant; otherwise the calibration of the instrument will be interfered with. This means that arcing or pitting, which occurs on all contacts carrying an appreciable amount of current in inductive circuits, must be eliminated. Experience has indicated that circuits with measurable inductance are not suitable for the purpose and that with non-inductive circuits, consumption less than one watt is highly desirable. The performances of some typical instruments are tabulated in Table I.

For research purposes it may be of interest to record wave form of acceleration. Interpretation of a record representing the accelerations caused by even a few feet of roadway assumes such proportions that the method is totally impractical for other than research work where the acceleration resulting from a single road obstruction is being studied. The method of counting provides a good way of arriving at performance over any desired length of road. To date it is subject to the instrument limitations above mentioned. The practical instrument must be capable of quick and convenient use over any desired length of roadway and provide a single total at the end of the run. This value must be a numerical expression of known physical constants to enable correlation of successive tests on different equipment or under any conceivable performance condition.

Extensive investigation resulted in the evolution of the Firestone Integrating Solenoid Accelerometer, Fig. 2. The instrument uses an actuating element similar but reduced to less than one-half the size of that used in previous solenoid instruments. A simple circuit was found which would accurately actuate the rotor of a modified single-phase induction watthour meter, in proportion to the duration of the acceleration exceeding the values to which the independent accelerometer elements were adjusted.

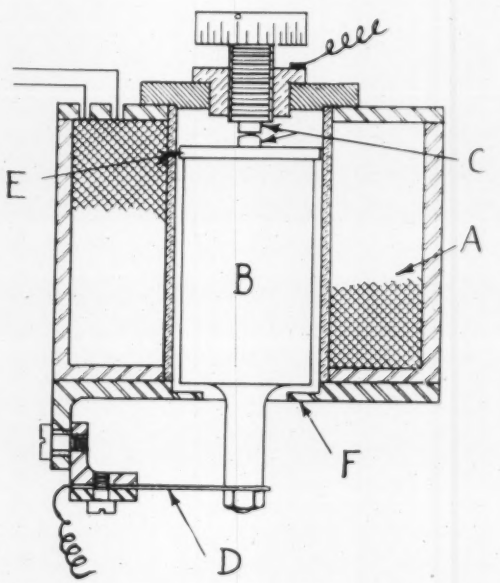


Fig. 1. Solenoid accelerometer element—Current in iron-clad solenoid winding A lifts iron core B until contacts C are closed. Acceleration acting along the axis of the core, when sufficient, over-balances the magnetic pull and the contacts open. Recording, counting or integrating devices are arranged to operate when the contacts open. The core is guided in the solenoid at points E and by cantilever spring D. The latter also serves as an electrical connection. Downward motion is limited by mechanical stops. A number of elements adjusted for successively higher values may be assembled in a single case.

[1] *Instruments*, Vol. 8, Nov. 1935, pages 290-291.
[2] *Instruments*, Vol. 2, April 1929, pages 123-124.
[3] *Instruments*, Vol. 8, Nov. 1935, page 289.
[4] U. S. Patent No. 2,034,649.
[5] *S.A.E. Journal*, Nov. 1926, page 433; Aug. 1927, page 121.

This instrument provides at the end of the run a single figure which represents either gravity minutes or, if desired, the time during which accelerations exceeded the calibrated value—both methods being the totalized value of two known physical constants, acceleration and time. Numerous circuit combinations are, of course, possible. The arrangement found simplest and most suitable is shown in Fig. 3.

The actuating element, being separate from the main instrument, can be located where desired; for example, on the axle, any portion of the frame, various parts of the engine and transmission, floor boards, seat cushions and fenders. The range can be conveniently and quickly changed by adjusting a rheostat permitting more or less current to flow through the solenoid of the elements. Connections are of the plug-in type which permits interchanging a counter or a chronograph, according to whether total number or record is desired.

The instrument can be conveniently calibrated so that the integrator reads a single totalized number indicating comfort. The arrangement is such that the calibration can be made to coincide with any desired comfort index.

The accelerometer element is so constructed that it can be used both in vertical and horizontal planes. With suitable calibration, two or more instruments can be plugged in series. The instruments could, for example, be arranged to integrate in a single totalized value the accelerations occurring in four planes: vertical and horizontal, transverse and longitudinal, which occur on the seat cushions, on the floor boards or axle or any combination thereof.

The car battery service is the only required source of energy. Suitable extension leads and all other required accessory equipment are provided in a single carrying case This makes it convenient to measure in a single test run, with one instrument, all of the accelerations that are significant to the passengers' comfort which occur in motor cars while in normal use in traveling over road surfaces.

TABLE I—TOTALIZING INSTRUMENT CHARACTERISTICS

Description	*Circuit*	*Volts*	*Watts*	*Max. Speed of Operation*[1]
Impulse Counter and Interval Timer, Magnetic Escapement Release Type	Inductive	18 AC 6.9 DC	2.34 V A 3.47	46
Electric Timer, Synchronous Motor Magnetic Clutch and Brake Type	Highly Inductive	6.9 DC	11.9	12
Electric Timer, Synchronous Motor Dynamic Brake Type	Inductive	(110) AC (10) AC	0.87 V A	5
Electric Register, Magnetic Ratchet Type	Highly Inductive	6 DC	1.0	15
Cycle Counter, Magnetic Polarized Escapement Type	Non-Inductive	11.8 DC	1.1	60
Firestone Electric Counter, Magnetic Polarized Escapement Type	Non-Inductive	1.45 DC	1.58	150
Firestone Integrator, Induction Watthour Meter Type	Non-Inductive	0.5 AC	0.032	60[2]

[1]Cycles per second to cause errors exceeding 2%; circuit closed intermittently, ½ time on, ½ time off.
[2]Equal to frequency used. Values given are for 60-cycle supply.

Fig. 2. Firestone Integrating Accelerometer—The comparatively small actuating element is placed on the motor car where it is desired to measure accelerations.

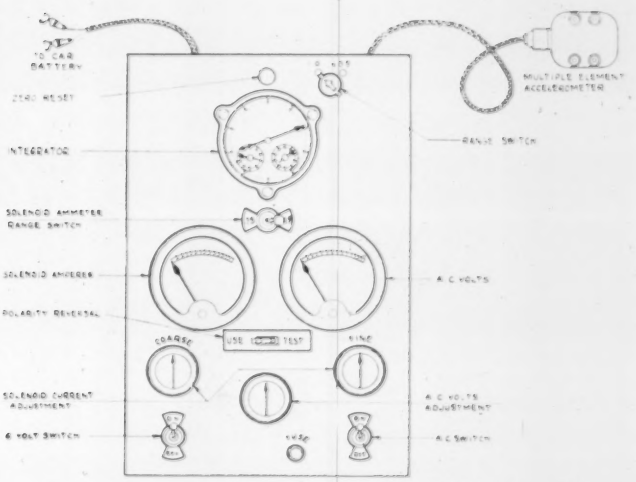


Fig. 3. Diagrammatic layout—The 6-volt supply from the car battery is converted into 110 volt, 60 cycle, a portion of which is passed through the accelerometer contacts. The time each of these contacts remains open due to accelerating the instrument is totalized on the integrator dial. The acceleration at which the elements operate may be varied as desired by adjustment of the solenoid current. A range switch is provided to double the integrator indication for short tests.

Review of Instruments and Results of Tests

By C. A. TEA

Research Engineer, Chrysler Corporation, Detroit, Mich.

IN its present state of development the automobile is unique in its unresponsiveness to simple instrument measurement of its comfort. The reason is obvious: It has eighteen degrees of freedom as a vibrating system, six for the body, and six for each axle and wheel assembly. Three for the body are highly important ones, which may be described as follows:

1. Vertical vibration of body.
2. "Pitching" or angular vibration about transverse axis.
3. "Rolling" or angular vibration about a longitudinal axis.

To make matters worse, we find in most cars that No. 1 and No. 2 coexist under operating conditions, complicat the dynamics and providing all the more reason for instrument testing on the road.

The objective is, of course, to measure and combine all appreciable accelerations into a single reading in proportion to their physiological effects on the passenger. Since cushions are a part of the suspension, forming another vibration system with the passenger as its mass, it is essential to take the measurement of forces on the seat cushion for the ultimate effect upon the passenger.

The vibrometer, or seismic, class is based on the principle that a mass suspended on a spring stands still when its spring is acted on by periodic forces having a frequency two or more times the natural frequency of the mass-and spring system. This does not give sufficient information on a graph without laborious analysis of the conditions of the ride.

The gyroscopic class which measures angular velocities is of some value in research type of work, but its primary records are incomplete, so that it, too, may be eliminated from a list of practical instruments.

This then leaves the accelerometer class as the ideal one for riding comfort measurement. This class may be divided into contact and graphic recording types, both of which have had considerable usage in the automobile industry with more or less success. According to the sub-committee's conclusions, however, the acceptable instrument should be capable of giving one reading on the condition of a ride, or two readings applying to horizontal and vertical forces, and should be based on the principle of integrating acceleration magnitude and time lapse.

The dummy passenger type, which rests on the seat and receives the same forces as a passenger, is in our opinion—at the present time at least—most nearly ideal for routine testing, due to the fact that constant bearing contact with the seat cushion insures constant conditions. Also, it enables the driver to conduct a test alone.

The application of any instrument to the cushions is of great importance, since the forces should be received as the passenger receives them in order to make possible a true quantitative result.

RESULTS OBTAINED WITH INTEGRATING TYPE

The Chrysler accelerometer adds up all accelerations during the test trip in proportion to their magnitudes and time of application; also, gives a higher reading on larger amplitude for the same acceleration. (Note—The newest model, Fig. 1, has a frequency adjustment which may in some cases be desirable.) In using the instrument, it is sufficient to adjust the element to such an angle as to record both vertical and pitching forces simultaneously, giving a resultant equivalent riding factor. Since this factor does not include "rolling" it may be discounted on the grounds of incompleteness; but one must remember that rolling, while it is relatively bad as a type of vehicle motion, is actually of so small value in reality (on most roads traveled today) that it is seldom even noticed.

It is also notable that as vehicle weight distribution is improved, there is a tendency to minimize "pitching" in the car and, no doubt, the day will come when vertical accelerations will predominate and their measurement will possibly constitute a fairly accurate criterion of the

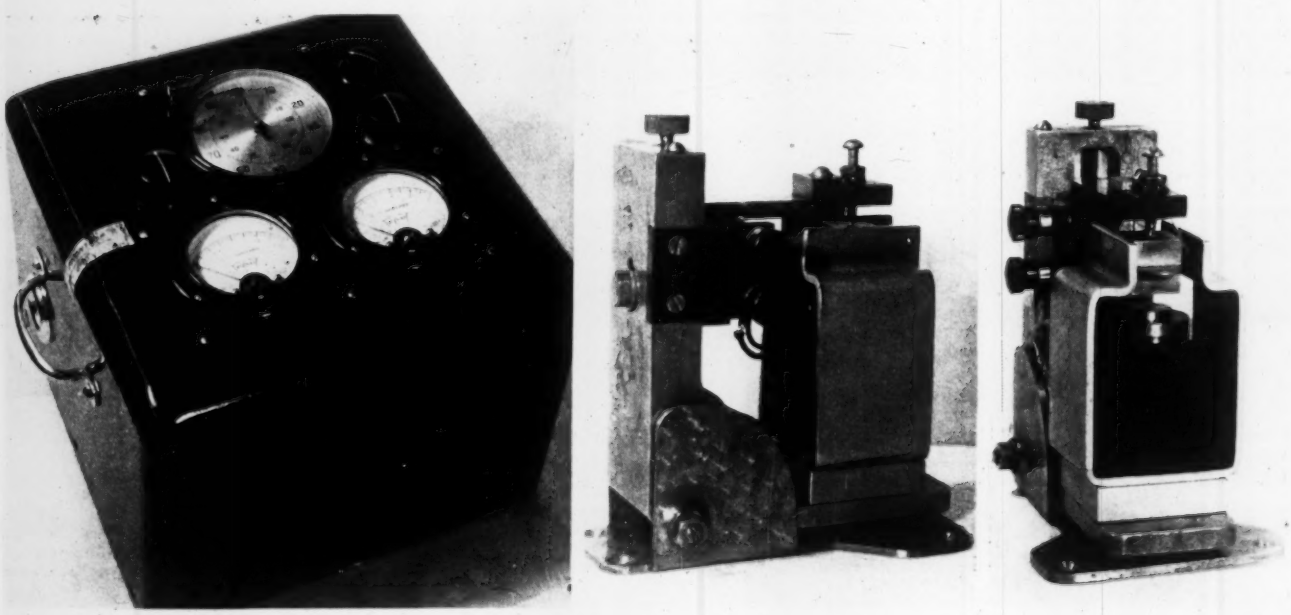


Fig. 1. The new Chrysler Riding Comfort Accelerometer.
General view of assembly, showing self-contained design. Two views of the primary acceleration-responsive element.

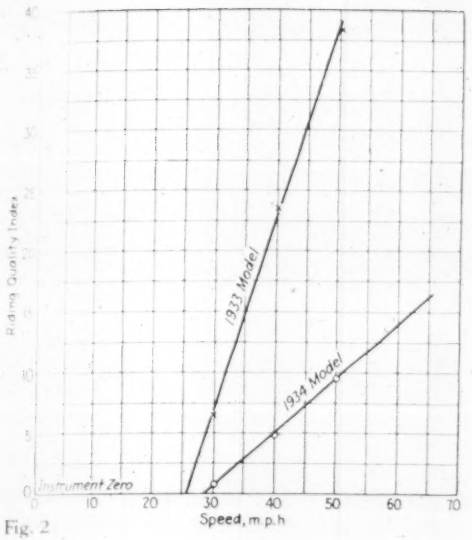


Fig. 2

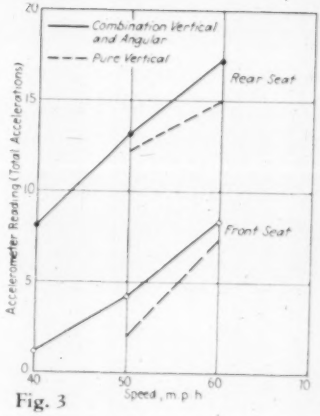


Fig. 3

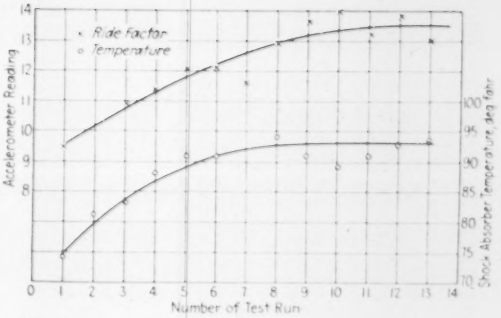


Fig. 4

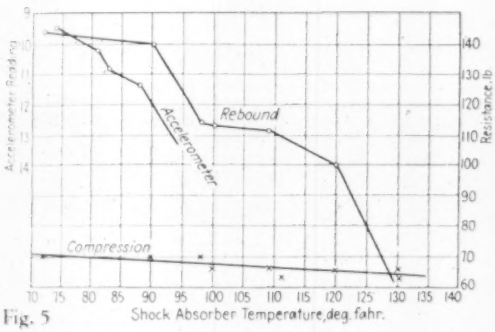


Fig. 5

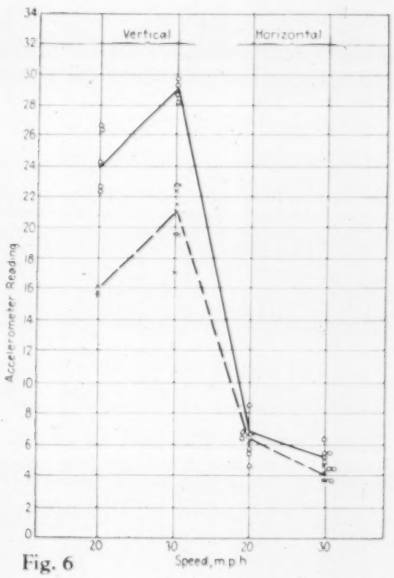


Fig. 6

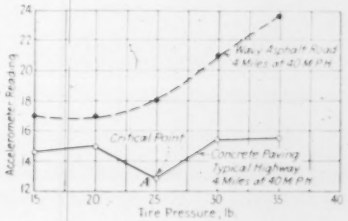

Wavy Asphalt Road 4 Miles at 40 M.P.H.
Critical Point
Concrete Paving Typical Highway 4 Miles at 40 M.P.H.
Accelerometer Reading
Tire Pressure, lb.

Fig. 7

ride of the car. This is particularly true in cars which have a weight distribution according to $K^2/AB = 1$ or $K^2/AB > 1$, the latter condition tending to cause a rise of the body at both axles when either front or rear wheels encounter a bump in the road. The quantity K is the radius of gyration about the center of gravity in the vertical plane; A and B are the distances from front and rear axles to the center of gravity.

RESULTS OF TESTS

Since the last meeting of the Riding Comfort Subcommittee we have collected additional road test data with the integrating accelerometer in various studies which attest further to the usefulness of a practical and reliable instrument in saving time and eliminating doubt from investigation of riding comfort.

The following investigations have been satisfactorily concluded by employment of our integrating accelerometer:

1. Difference in ride on the rear seat of one model car from one year to the next, showing advance made in that product. (Fig. 2.)

2. Relative effects of horizontal and vertical components on riding comfort in both front and rear seats, checking average opinion of six disinterested parties. (Fig. 3.)

3. Suspected loss of control of shock absorbers due to normal heating up in driving the car over a wavy road. (Figs. 4 and 5.)

4. Indication of numerical vibration effects of different bracings of frame and body in a particular car at various speeds over a given gravel road, which led to improvement in construction. (Fig. 6.)

5. Effect of tire pressure in six-ply tires on certain roads at various speeds. A critical pressure for maximum comfort was discernible by the instrument on one particular road that was otherwise not definitely recognized. (Fig. 7.)

6. Reliability of instrument readings and effect of a shock absorber valve change. (Chart I.)

Instrumentation is vitally needed by engineers studying routine riding comfor problems day by day. A satisfactory instrument that gives an answer to a change in the suspension saves days, sometimes months, in arriving at solutions to problems, and furnishes the engineer assurance that certain changes in the elements of suspension affect the ride certain ways

CHART I—RIDING QUALITY TEST

1. Object:
To determine effect of valve change in shock absorbers on vertical accelerations of chassis of six-cylinder, 1935 sedan on wavy road.

2. Location of Instrument:
Accelerometer bolted to rear floor boards close to frame side rail with rubber pad interposed.

3. Speed:
50 miles per hour.

4. Road Conditions:
Surface—asphalt, undulating.
Distance—5 miles North; and 5 miles South.

5. Results:

Runs	*Std. Prod. Car*	*Same (with slight change in shock absorbers)*
North 1	91.86	96.97
2	93.48	97.0
3	93.48	
South 1	101.50	103.00
2	100.22	103.10
3	102.91	

Note: The difference in ride was just noticeable. The reliability of the instrument is indicated by its ability to repeat within a few percent.

A New Moisture Indicator for Wood

By M. E. DUNLAP

Senior Engineer, Forest Products Laboratory[1], Forest Service, U. S. Department of Agriculture

FOR several years investigators at the Forest Products Laboratory have striven to develop a means for the rapid determination of the moisture content of wood and other hygroscopic materials. Considerable success has been had in this field, particularly with electrical instruments. Such devices, however, are relatively expensive.

One of the earliest instruments for determining moisture content, the wood hygrometer, partially filled the need for an inexpensive instrument, but it was never commercialized because it could not be shipped successfully: mercury was used, and rough handling impaired calibration.

Promising to meet the low-cost need, a new instrument has been worked out employing the relationship between relative humidity and moisture content of hygroscopic materials. If wood is exposed to a given relative humidity it will approach a definite moisture content and conversely if wood of a given moisture content is confined in a small space, the humidity about it will become constant and approach equilibrium with it. Thus all that is necessary to determine the moisture content of wood is to measure the humidity in contact with it.

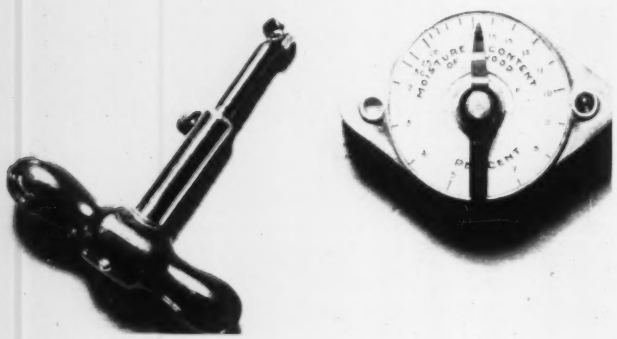


Fig. 1

This is accomplished with the new instrument by drilling a $\frac{1}{2}$" hole, a little over $1\frac{1}{2}$" deep, in the lumber to be tested and measuring the humidity that develops therein.

The instrument is shown in Fig. 1, together with a ratchet hand drill for making the hole. From the under side of the instrument projects a short perforated tube in which is mounted a small piece of goldbeater's skin 0.25" wide and 0.30" long. One end of this element is attached to the tube, the other to a light spring lever by a fine wire which moves a target up and down as the humidity varies. Mechanically, this is all that the moisture-sensitive element must do. It does not actuate an indicating device and hence may be extremely light and sensitive.

The measurement is made by manually rotating the pointer to which is attached a screw, the point of which moves down to meet the target and upon contact flashes a small electric lamp. The position of the pointer then represents the moisture content of the wood under test: the drier the wood, the further the screw must be turned to make contact. The power is furnished by two small "pen-lite" cells connected in parallel. The light throws a bright beam readily seen in daylight.

Calibration may be made by exposing the element to blocks of wood of different moisture contents and recording the points on an arbitrary dial scale. Then the blocks are oven-dried, their moisture contents computed, and the points plotted on a chart (as in Fig. 2) showing the relation between moisture content and the arbitrary scale. For convenience, the arbitrary scale may be converted into one registering moisture content (by projecting calibration points as shown at the bottom of Fig. 2) to make a direct-reading instrument.

Fig. 3 illustrates the rapidity with which the instrument responds to a change in humidity. Starting at points A and B on the chart the approach to equilibrium under several different conditions is shown. The ultimate moisture content was reached within a few minutes after the change in exposure took place.

Such an instrument should find utility where only a small number of tests is required. It should work out well for the inspection of material by architects and engineers. Several modifications may be easily worked out whereby it may be used to measure the moisture content of a variety of hygroscopic materials.

A patent dedicated to the public is being applied for, so that anyone wishing to do so may make the instrument for use or sale, subject of course, to the rights of others not known to the F.P.L. The instrument is not yet available, but as soon as its manufacture is taken up an announcement will be made. Those interested in the manufacture of the instrument may consult members of the F.P.L. staff if further information is needed.

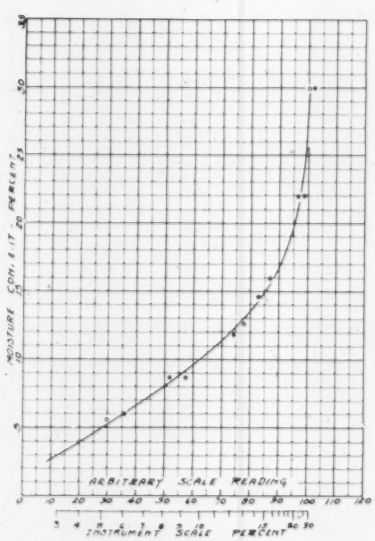


Fig. 2. Calibration curve.

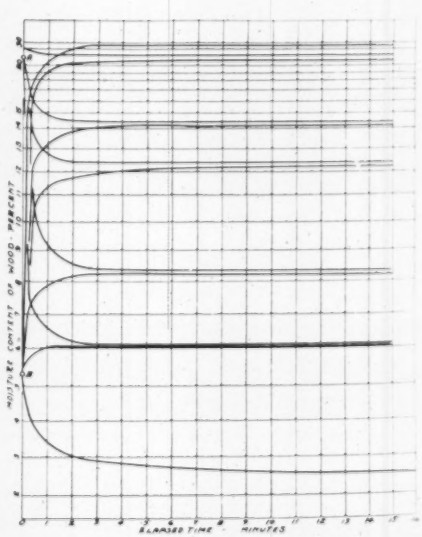


Fig. 3. Moisture content equilibrium curves.

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Carbon-monoxide Indicators for Aircraft*

By S. H. J. WOMACK and J. B. PETERSON

Aeronautic Instruments Section, National Bureau of Standards, Washington, D. C.

AT normal atmospheric pressure, the maximum concentration[1] of carbon monoxide to which a person may be exposed without harm for one hour is 0.04% by volume. More recently Diringshofer and Hartmann[2] conclude that the permissible concentration by volume is 0.02% at zero altitude and falls to 0.005% at about 15,000 feet. Carbon monoxide in quantities dangerous to personnel may be present in the cockpit of an airplane or in the engine nacelle of an airship by reason of such causes as (a) a leak in an exhaust line when the exhaust from the engine is used to heat a cabin or compartment, or (b) an unforeseen condition of air flow resulting in flow of exhaust gases into the cockpit of an airplane. It therefore is advisable to have a carbon-monoxide indicator suitable for use in aircraft. In some cases a permanent installation is desired; in others merely a test to insure that the air flow about the aircraft is not such as to carry the engine exhaust into the cockpit or cabin.

The carbon-monoxide indicator, modifications of which are here discussed, was made by the Mine Safety Appliance Co. (MSA). The story of the development of this type of carbon-monoxide indicator has been published[1,3,4]. Other types of instruments have been developed[5,6,7,8]. The instrument consists essentially of

(a) a means for continuous sampling of the air to be tested,
(b) a chemical for absorbing moisture,
(c) a cell in which the CO is converted to CO_2, and
(d) an indicator of the rise in temperature of the cell, which is graduated in terms of percentage of CO.

White[9] gives the results of tests on U. S. Navy airplanes using indicators of this type.

At the request and with the coöperation of the Bureau of Aeronautics of the Navy Department, certain of the commercially supplied instruments have been modified to make them more suitable for use on aircraft. These modifications have included

(a) the addition of a regulating valve for automatically controlling the rate of flow of the air being sampled,
(b) the use of a source of suction external to the instrument, and
(c) remounting parts so as to reduce weight and size.

An alarm was perfected and added to an instrument intended primarily for airship use. Methods of test have been developed and performance data have been accumulated.

*Condensed from National Advisory Committee for Aeronautics *Technical Note No. 573*, 1936. Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[1]S. H. Katz, D. A. Reynolds, H. W. Frevert & J. J. Bloomfield. A Carbon Monoxide Recorder and Alarm. *Bureau of Mines Technical Paper No. 355*, 1926.

[2]H. v. Diringshofen & H. Hartmann. Kohlenoxyd und Höhenwirkung (Altitude Effects of Carbon Monoxide). *Luftfahrtforschung*, Vol. 12, July 30, 1935, pages 121-123.

[3]W. W. Frevert & E. W. Francis. Improved Analyzer for Carbon Monoxide in Air. *Industrial & Engineering Chemistry (Anal. Ed.)*, Vol. 6, 1934, page 226.

[4]A Continuous Carbon Monoxide Indicator. *Journal of Scientific Instruments*, Vol. 9, 1932, page 327.

[5]S. S. Tomkins. Gas Detection Instruments. *Proceedings American Gas Assn.*, 1932, page 810.

[6]A Carbon Monoxide Detector. *Chemical Age* (London), Vol. 28, 1933, page 463.

[7]O. Pfundt. Carbon Monoxide Recorder. *Die Chemische Fabrik*, Vol. 6, 1933, page 69.

[8]Details of the Carbon Monoxide Recording Apparatus of the Ventilating Installation in Mersey Tunnel. *The Electrician*, Vol. 111, 1933, page 309.

[9]Joel J. White. Carbon Monoxide and its Relation to Aircraft. *U. S. Navy Medical Bulletin*, Vol. 30, April 1932, pages 151-165.

[10]J. C. W. Frazer & C. C. Scalrone. U. S. Patent 1345323, June 29, 1920.

DESCRIPTION OF MODIFICATIONS

In the instrument as usually furnished, a motor and a vacuum pump are provided to draw the sample of air through the instrument. This arrangement is not ideal for aircraft in all cases since a source of current is needed for the motor and—more important—the bulk of the instrument adds to the inconvenience of installation. In the improved arrangement the source of suction is external to the instrument and may conveniently be the intake manifold of the engine or a small Venturi tube mounted in the slip stream. Fig. 1 is a schematic diagram of the air flow in the carbon-monoxide indicator so modified. Air that is being tested, flows continuously through a canister containing a chemical drying agent, a capillary tube type flow indicator, a hopcalite cell and, in the case of the modified instrument, the flow regulator.

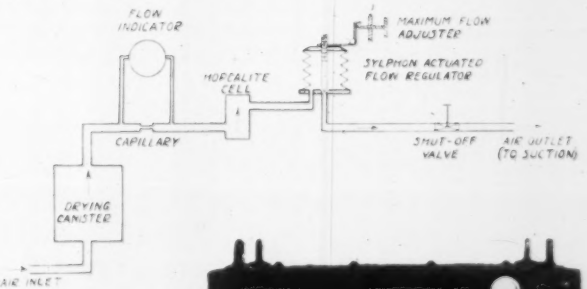


Fig. 1. Diagram of airflow in a modified carbon-monoxide indicator.

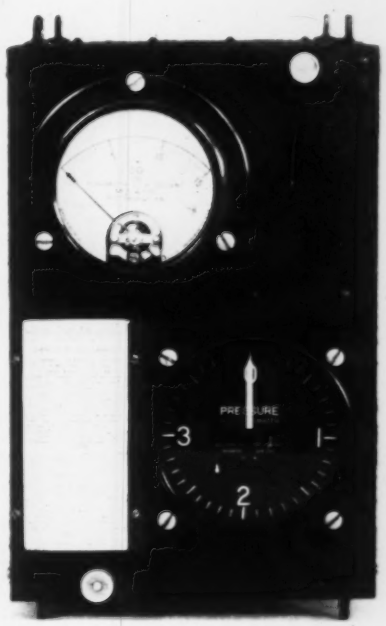


Fig. 2. View of modified carbon-monoxide indicator.

From this point on the description will be confined to the modified instrument (Fig. 2). The heart of the instrument is the hopcalite cell[1,10] in which the carbon monoxide is converted to carbon dioxide. Hopcalite is the trade name for a granular mixture of manganese dioxide and copper oxide, which serves as a catalyst for the reaction. One end of the hopcalite cell is filled with active chemical; the other end with inactive chemical. A series of thermocouples is used to measure the difference in temperature between the inactive and active parts of the cell. The output of the thermocouples

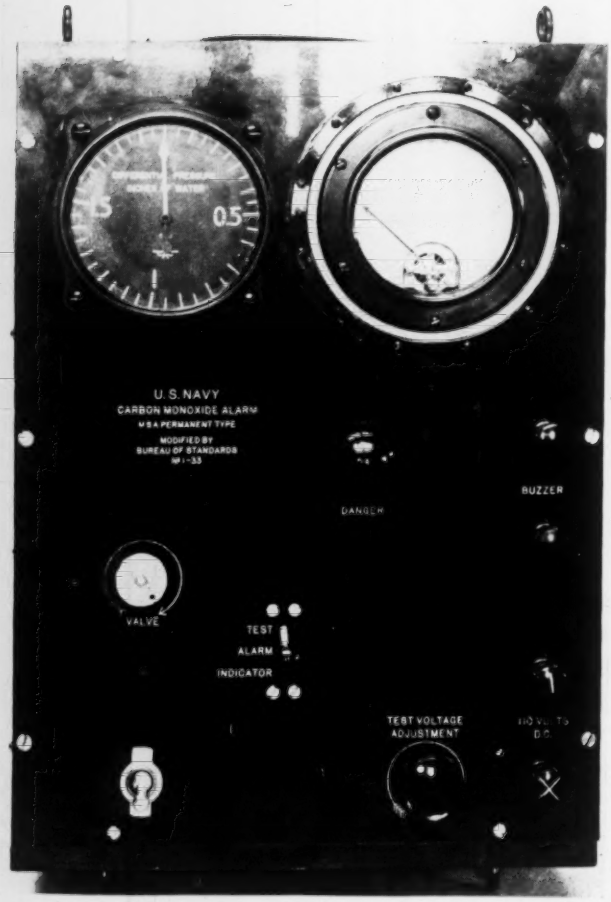


Fig. 3. View of carbon-monoxide indicator and alarm.

is indicated by a voltmeter graduated to indicate CO content in the range 0-0.15%. The millivoltmeter supplied with the instrument has a range of approximately 20 millivolts for full-scale deflection and a resistance of 65 ohms.

In view of the variation that may be experienced in the external sources of suction, such as a Venturi tube, it was thought essential to provide an automatic flow regulator. The flow regulator is actually a suction regulator that maintains a constant suction inside of the metal bellows (Fig. 1). It follows that if this suction is constant the volume flow will also be constant. The rate of flow is adjustable over a wide range by means of the vertical valve stem at the center of the bellows and over a shorter range by means of the manual adjustment. This adjustment consists essentially of a flat spring, the pressure of which on the top of the bellows is adjustable by means of a screw.

The flow indicator is of the capillary-tube type. A diaphragm-type manometer was substituted for the U-tube manometer used in the commercial instrument.

The modified instrument (Fig. 2) is mounted in a $5\frac{1}{2}'' \times 5\frac{1}{2}'' \times 8\frac{1}{2}''$ aluminum case. It weighs 8.0 lbs.

ALARM ATTACHMENT

At the request of the Bureau of Aeronautics an alarm to indicate the presence of CO in excess of 0.02% was added to an MSA instrument in 1933. The instrument was designed and constructed for continuous operation on the U. S. airship *Akron*. At the time this alarm attachment was made, the suction-operated instrument previously described had not been developed; therefore,

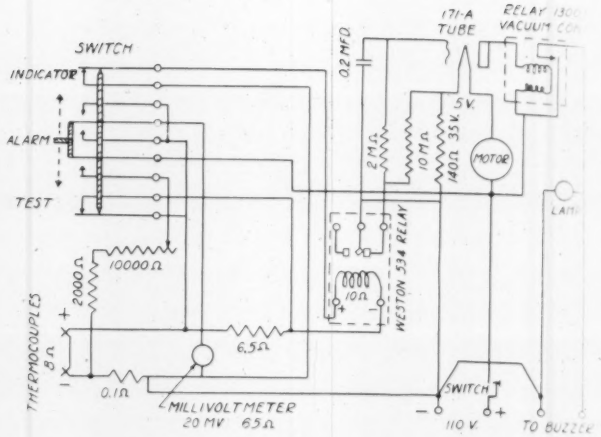


Fig. 4. Diagram of electrical circuit of the alarm.

an instrument with a motor-operated pump was used. An external source of suction is probably preferable for future alarm instruments.

A front view of the instrument with the alarm attachment is shown in Fig. 3.

Fig. 4 is a wiring diagram of the alarm. The telephone switch marked "test," "alarm," and "indicator" on the panel (see Fig. 3) normally stands in the "alarm" position unless manually held in one of the other positions. When in the "alarm" position, the output of the thermocouples in the hopcalite cell goes directly to a Weston Model 534 relay. The relay controls the grid circuit of a type 171-A vacuum tube. A Burgess vacuum contact relay in the plate circuit of the vacuum tube controls the danger signal light ("danger," in Fig. 3) and the buzzer alarm.

The percentage of carbon monoxide in the sample is indicated on the electrical instrument when the switch is held in the "indicator" position. If the instrument has been in continuous operation on the "alarm" position the indicator may be read immediately after the switch is moved to the "indicator" position.

In order to test the operation of the relays and alarm apparatus, a means of applying a voltage to the first relay equivalent to that produced by air containing 0.02% CO is provided. The telephone switch is held in the "test" position and the "test voltage adjustment" knob slowly turned up until the pointer of the electrical indicator reaches the 0.02% mark. The alarm signals should then operate after about 4 seconds. (The purpose of this 4-second lag will be explained in the next paragraph.) Failure to operate in this test indicates need for adjustment of the electrical circuit as, for example, adjustment of the relay contacts. The frequency of test must be determined by experience.

The lag mentioned in the preceding paragraph is produced by a capacitor installed across the contacts of the sensitive relay in the grid circuit of the vacuum tube. The contacts of the relay are normally closed and, with the capacitor in the circuit, remain open for about 3 or 4 seconds before the alarm signals operate. Hence a continuous voltage must be maintained on the relay before it will operate. This arrangement prevents false alarms due to a momentary opening of the contacts caused by excessive vibration of the instrument. The capacitor also reduces the amount of sparking at the contacts of the sensitive relay.

The buzzer alarm or horn is external to the instrument and is connected to the electrical circuit at the binding posts marked "buzzer" on the panel.

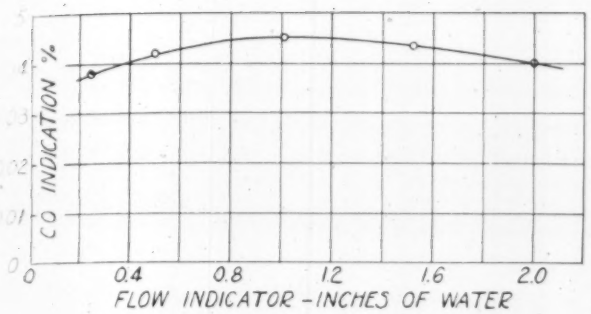


Fig. 5. Effect of rate of sampling on the indication.

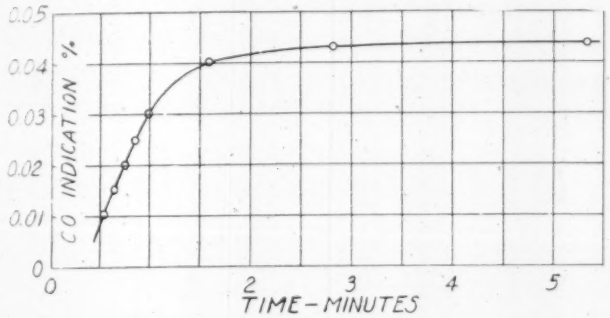


Fig. 6. Time-response characteristic of carbon-monoxide indicator when flow indicator reads one inch of water.

The power requirement of the apparatus is 0.25 amp., 110 volts d.c. As shown in the electrical diagram, the vacuum-tube filament and the vacuum-pump motor are in series. The characteristics of the circuit are such that the vacuum-tube filament is not injured by the normal starting current of the motor.

PERFORMANCE CHARACTERISTICS

Tests of the carbon-monoxide indicators show the following:

1. The e.m.f. developed in the hopcalite cell is directly proportional to the CO content of the sample, within the limit of accuracy of the method of analysis of the CO-air mixture (iodine-pentoxide method, limit $\pm 0.003\%$).

2. For a mixture containing 0.05% CO, the maximum indication occurred when the pressure gage of the flow indicator indicated approximately 1" of water. The CO indication is plotted against indication of flow in Fig. 5, where it is seen that the CO indication decreases 2% at differential pressures of 0.75" and 1.35" of water.

The rate of flow of gas through the hopcalite cell has been selected so that the instrument is normally operated on the flat top of the curve shown in Fig. 5, in which region the CO indication is practically independent of the rate of flow. Assuming that the flow is manually held constant, the CO indication decreases as the air pressure decreases. Laboratory tests in an altitude chamber have checked this characteristic at altitudes to 13,000 feet. However, if the instrument is constructed to operate at sea level at a greater rate of flow than that corresponding to the top of the curve (Fig. 5), the CO indication will not be appreciably affected by a large decrease in rate of flow and will thus be practically independent of altitude.

3. The indication of the instrument against time, after a sample of given CO content is started through the system, is shown in Fig. 6. Five minutes is a safe interval to wait before taking a reading.

4. No appreciable change in indication is obtained for changes in instrument temperature in the range from —5° to 40° C. The tests were made using an instrument with a fresh hopcalite cell. Excessive change in reading with temperature is an indication of the necessity of renewing the hopcalite cell.

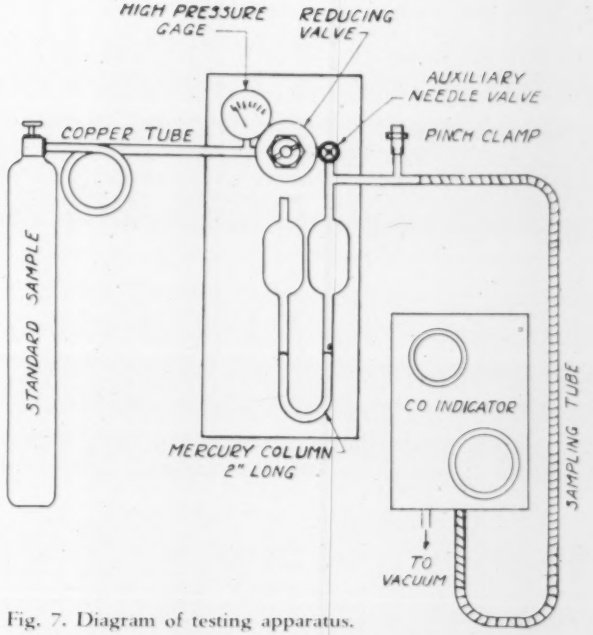


Fig. 7. Diagram of testing apparatus.

5. Within a wide range of suction the flow is held constant by the automatic flow regulator. A minimum suction across the indicator of about 4" of mercury is required for automatic operation. Operation on a suction as low as 1.5" of mercury may be obtained by discarding the automatic feature and securing constant flow by hand regulation of the manual regulating screw.

METHOD OF FIELD TESTING

It is essential under some circumstances to be able to test carbon-monoxide indicators in the field. The method developed for this purpose has also proved to be convenient and adequate for calibration tests in the laboratory. The arrangement of the apparatus is shown in Fig. 7. The standard sample is a cylinder of air at high pressure (2,000 lbs. in.$^{-2}$) containing a small accurately known percentage of carbon monoxide. If one cylinder only is available, it should contain about 0.03% of CO. Since the results of many tests indicate that the e.m.f. developed in the hopcalite cell is directly proportional to the CO content of the sample, it is thought that field tests at more than one point are unnecessary. A pressure gage for measuring the tank pressure and a reducing valve are mounted on a panel. A U-tube mercury safety valve, which serves primarily to protect the carbon-monoxide indicator from excessive pressure, is also used to indicate the input pressure.

An instrument to be tested is connected as shown in Fig. 7. A suction source must be provided if a suction-operated instrument is to be tested. The instrument is operated exactly as explained in operating instructions, except that the sample is drawn from the cylinder of known CO content. The fresh air for the preliminary operation of the instrument is drawn in at the pinch clamp. If the reducing valve reduces the pressure to a fairly low and constant value, it is easy to manipulate the auxiliary needle valve and the pinch clamp at the same time so that the flow is transferred from fresh air to the sample of known CO content without subjecting any part to excessive pressure or suction.

The time during which the CO sample is allowed to flow through the instrument should not be longer than necessary because of depletion of the sample and of the active hopcalite.

Fundamental Applications of the Cathode-ray Oscillograph

A synoptic part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1938 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

FREQUENCY COMPARISONS

In calibrating such a device as an audio oscillator against a standard which has an output of only a few frequencies (say 100, 1000 and 10,000 cycles) there is required an absolutely reliable method of interpolating, in order that the device may be calibrated accurately at intermediate frequencies. The cathode-ray oscillograph makes this possible. Rasmussen has described[1] a convenient method which is essentially as follows: A gear-wheel diagram which normally might appear as in Fig. 3 is elongated so that only the central portion of the top edge shows on the screen. This is done by increasing the amplitude of the frequency producing the time base, and applying suitable d-c. biasing voltages to the deflection plate circuit to shift the desired portion of the trace to the center of the screen.

It can be seen that if the higher frequency is a direct multiple of the base frequency, a distorted ellipse appears at low frequency ratios, or a gear shaped diagram at the higher frequency ratios. However, if the ratio is an improper fraction, a multiple or "woven" figure appears, of a type such as shown in Fig. 5a.

This effect is utilized to determine the intermediate frequency points of the calibration. A count is made of the number of times (L) that the trace intersects a reference line drawn anywhere perpendicular to the elongated axis. It has been shown that the ratio of frequencies is always equal to $N + (x \div L)$ where N is some integer and x is less than L and not having a common factor with it. For instance if the section of the pattern has three lines, Fig. 5b, the ratio is either ($N + \frac{1}{3}$) or ($N + \frac{2}{3}$). Such a system therefore can be used when the two frequencies have a quotient equal to an improper fraction with a denominator of any value up to 10 or 12 or possibly more. Fig. 5c shows four interwoven lines, and 5d five lines. It was also shown[1] that when woven patterns with as many as twelve lines were used, calibration points approximately 2% apart were obtained. Points closer than this can be obtained by noting the rate at which the figure shifts laterally when the frequency ratio differs a little from that of an improper fraction with a relatively small number for denominator. If the diagram shifts along the horizontal axis a distance corresponding to one cycle in one second, the frequency is equal to the standard times the above mentioned ratio ± one cycle, the sign depending upon the direction of the shift. Such a movement is readily noticed if a reference line is drawn on the end of the tube.

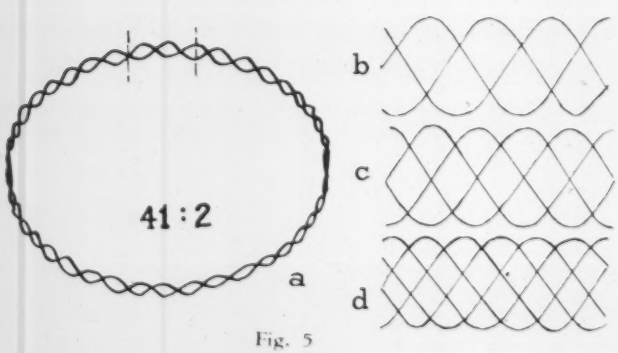


Fig. 5

TIME STUDIES

Setups similar to those used in the measurement of frequency may also serve for the measurement of extremely short time intervals, as in locating faults by measuring the time between the initiation of a pulse applied to the line and its return by reflection from the fault; studies of the ionosphere by timing radio echoes, and the analysis of the performance of internal-combustion engines under various ignition conditions. When the time interval is of the order of microseconds, the spot traverses the screen so rapidly that photographic records are generally required.

Either a high-frequency linear time base might be used, or else a circular time base having a high rotational speed so that the time interval that is to be recorded is spread out over a greater area. In the case of a circular time base the pulses representing the time interval under study are applied so as to produce radial excursions from the normal trace, as in the case of frequency comparisons.

Angular distances must be measured in this case, or else the distances along the circumference. In the first method the center of the circle (or ellipse) must be delineated by momentarily removing both deflection potentials at the same time. In the latter case the normal time base circle must be superimposed on the trace as well, so that the normal circumference is visible.

In the latter case, if the base is not a true circle but an ellipse, corrections must be applied to the circumference values, since equal distances along the periphery of an ellipse do not represent equal divisions of time. This can be done by a graphic method if the ellipse is undistorted. Construct a circle having a common center with the ellipse and a diameter equal to the projected length of the ellipse on one of the deflection axes, as in Fig. 6. Lines a and b, from the two points on the ellipse representing the time interval to be measured, are projected to the circle, being perpendicular to this axis, as indicated by the points a' and b'. The arc $a'b'$ between these intercepts represents the required time interval.

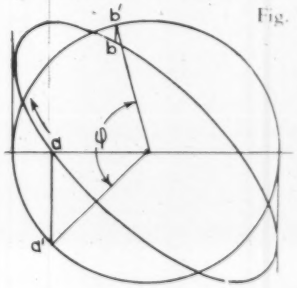


Fig. 6

DISCONTINUOUS DIAGRAMS

In many cases it has been found that the use of discontinuous diagrams, as described in the last issue, reduces the amount of work involved in the computation from the oscillograms, although the accuracy with this method is usually not as great. It is necessary to rotate the spot at a definite rate, say 60 or 1000 revolutions per second. As an example, assuming the former rate, if the stream is interrupted for an interval of 0.00 second an angular dark sector appears, approximately 65° in extent. The length of this sector is directly pro-

rtional to the time interval during which the modulation bias of the cathode-ray tube is altered. The process can be varied so as to reëstablish the cathode ray during the interval measured, having normally set the bias so that the ray is nearly extinguished. For longer time intervals than that corresponding to one revolution of the time base, several cycles of the spiral time base can be utilized, as described in the April 1936 article (page 115).

In another method the above procedure is reversed. A timing wave with a known frequency can be applied to the modulation grid of the cathode-ray tube so that the stream is interrupted at a known rate. Any configuration on the screen due to the application of any type of waves to the deflection plates will then appear as a row of dots. One method is to jerk this figure to a new position during the interval being measured, so that the number of dots on this offset section indicates directly the length of time. It is not essential to have a true circle, since a count of the dots only is necessary. To have a sufficiently large number of dots during the measured interval, the timing-wave period should be many times shorter than that interval.

PHASE EFFECTS

If two sinusoidal potentials of the same frequency are connected to the deflection plates, a straight line appears on the screen whenever both potentials are in phase. This matter has been described in the previous article and the gradual changes of the shape were shown: line—ellipse—circle—ellipse—line (now at right angles to the first line)—ellipse—circle—ellipse—line. Each complete series from a straight line back to a similar line pointing in the same direction represents a gain of one cycle in one of the frequencies, or in other words, a 360° shift.

A true circle will never be obtained unless the amplitudes of the two deflections are the same and the wave form sinusoidal. Since the sensitivity of the two pairs of deflection plates may not be equal, the actual potentials required to produce a circle must compensate for this difference. So in the above cycle of diagrams the term "circle" may actually refer to a vertical or horizontal ellipse, as distinguished from a sloping one.

Since cathode-ray tubes are so frequently used in phase studies, a brief analysis of this series of ellipses will follow. In Fig. 7a, the amplitude of one of the deflecting potentials has been increased from OA to OB and then to OC, without altering its phase relations with respect to the potential producing the other deflection. It will be seen that both the size and shape of the resulting ellipses are changed thereby. Inspection of the three curves discloses two similarities: the vertical projections of each ellipse on the x axis coincide at F, and all the curves intersect this axis at the same point at E. At the instant of time at which this intersection occurs, the frequency f is passing through zero, while the wave n lags by an angle whose sine is equal to $\frac{OE}{OF}$.

Therefore, using the customary notation with regard to the angles and their signs,

$$e_f = k\,(OF)\,\sin\,(\omega t + \theta)$$

where θ is $\arcsin\frac{OE}{OF}$ and k is a calibration constant of the tube (the relative sensitivity of the two pairs of plates).

In Fig. 7b the amplitude of the other potential was changed also without changing the phase relation. Although the values of both OE and OF are now altered, it will be found that their quotient remains unchanged, indicating that the results are independent of the relative amplitude of the deflections. This is the basic principle for determining the phase difference between certain separate parts of any electrical circuit.

In Fig. 8 the curves X, Y, and Z represent a phase change between certain points in a circuit, that is the curve X gradually changes; passing through the shape Y and ending with the shape Z. This change represents an amount equal to

$$\sin^{-1}\left(\frac{OC}{OF}\right) - \sin^{-1}\left(\frac{OA}{OF}\right)$$

These conditions will hold even if one of the potentials varies in intensity, provided that the other remains constant. If both potentials vary, an instantaneous photograph must be taken to determine the phase difference, even if the latter remains unchanged. These determinations are not conclusive when the figure is approximately a circle, or when the ellipse is so narrow that it approaches a straight line. In either of these cases a tangent to the curve might be drawn perpendicular to the vertical axis of the screen. The ratio of the distance from this axis and the point of tangency, to the maximum deflection in the horizontal direction is equal to the sine of the phase angle. The accuracy of the latter determination depends upon the correct estimation of the location of the point of tangency. It is desirable, if possible, to shift one of the applied potentials 90° whenever the ellipse to be measured is nearly a circle. In the case of narrow ellipses, the value of the sine θ can often be obtained more readily from the relation:

$$\sin\,\theta = \frac{r^2 + 1}{r} \times \frac{WW'}{LL'}$$

where $r = \frac{YY'}{XX'}$ in Fig. 9. Should the deflections be accurately adjusted so that $r = 1$ the process is much simplified since $\sin\,\theta = 2\frac{WW'}{LL'}$

As in the previous cases, however, the allowance must be made for the width of the line itself in the determination of all distances.

In the study of phase relationships in the more complicated diagrams, such as illustrated in Fig. 2, it may help if these figures are considered as long narrow ellipses wound around a transparent cylinder. From this

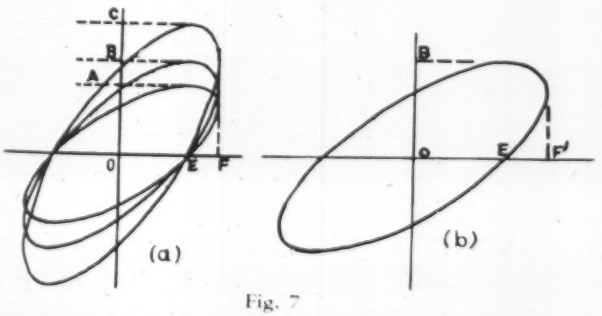


Fig. 7

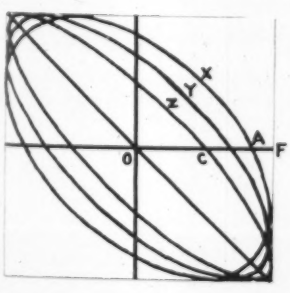


Fig. 8

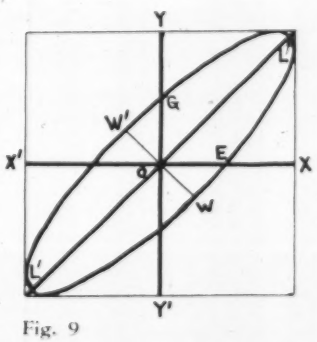


Fig. 9

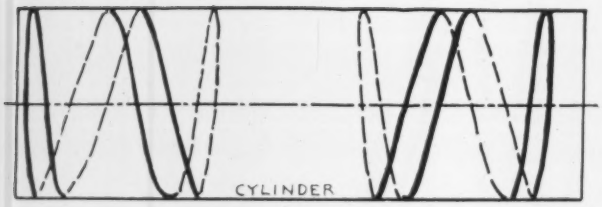


Fig. 10

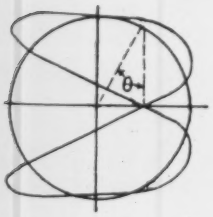
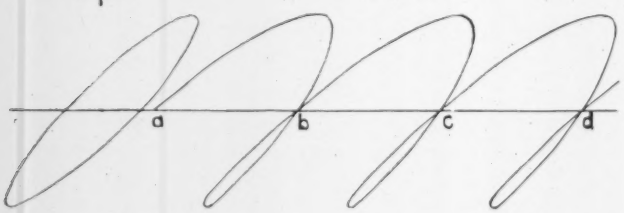


Fig. 11

Fig. 12



viewpoint even the single line figures are types of ellipses. In Fig. 10 one diagram of the series in Fig. 1 has been redrawn to indicate the cylinder. It will be noted that every possible variation of the phase relations between n and f (where $f = 4n$) will be delineated if the cylinder is viewed successively from all directions perpendicular to its axis.

The determination of the phase displacement between waves having harmonic relations with each other can be done in the same way. Refering to any of the diagrams in Figs. 1 or 2, it will be noted that whenever the frequency ratio is an even number the trace cuts one of the axes at but one point. As before, the relation between the distance to this intercept and the maximum deflection is equal to the sine of the phase angle (see Fig. 11). When odd frequency ratios are encountered two or more intersections are found, any one (or all) of which values can be substituted in the same formula.

HIGH FREQUENCY PHASE STUDIES

In most cathode ray tubes, both phase and amplitude distortions occur when extremely high frequencies (over one megacycle) are impressed on the plates. A finite interval of time is required for the ray to pass from the center of one pair of plates to the center of the other pair. As an example, if the anode voltage is 500 volts the speed of the rays may be less than 4% of the speed of light. If the distance between the centers of the deflection plate pairs is 3 centimeters measured along the axis of the tube, the phase error is about one degree when a frequency of one megacycle is studied. At higher frequencies this error is proportionally greater.[11]

To correct for any error due to this effect, the ratio of the distance the trace intercepts the vertical axis to the maximum deflection, must be averaged against the horizontal intercept to the maximum horizontal deflection. In other words the phase angle is more nearly equal to $\sin^{-1} \frac{1}{2} \left(\frac{OG}{OY} + \frac{OE}{OX} \right)$ refering to the symbols in Fig. 9. The effect of amplitude distortion due to frequency characteristics was described in the Dec. 1935 article.

[12]Harris, Cathode-ray Oscillograph in the Study of Power Losses, *Bureau of Standards Journal of Research*, Vol. 12, 1934, pages 87-102.
[13]Batcher, Applications of the Cathode-ray Oscillograph, *Proceedings Institute of Radio Engineers*, Vol. 20, 1932, pages 1878-1891.

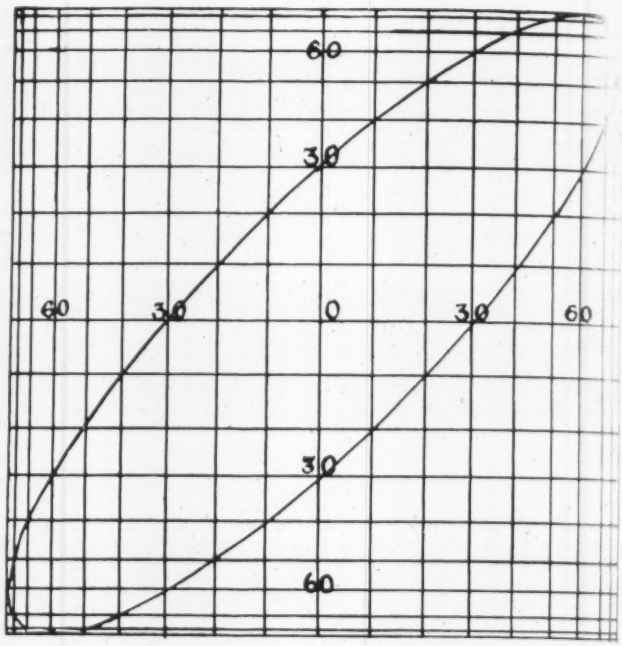


Fig. 13

ANALYSIS OF ELLIPTICAL RECORDS

In the usual condenser test for dielectric losses a narrow ellipse is the basis of all measurements. The accuracy is therefore low, by reason of the difficulty in estimating the length of the minor axis, due to the relatively wide line with which the ellipse is traced.

The author usually finds it more convenient to move the ellipse laterally along one of the deflection axes, so that a series of loops is produced, as in Fig. 12.

If the speed of this lateral translation is adjusted so that the points where the loops intersect (as at a, b, c, etc.), are on the x axis of the screen it will be found that the minor axis is then equal to $\frac{1}{4}$ (ab) $\sin \theta$.

Since $ab = \frac{1}{2}ac = \frac{1}{3}ad$, etc., its value can be determined across several loops with much greater accuracy. This method calls for a carefully adjusted linear timing oscillator for moving the ellipse laterally. The value of θ can be found readily from the ellipse itself when stationary.

A formula for determining the phase displacements for other rates of lateral translation has been published by Harris[12] who gives a general solution to this problem, and reports practical tests on the power-factor of condensers.

SCREEN CALIBRATION SCALES[13]

A phase checking scale made after the arrangement shown in Fig. 4c of the December 1935 article, wherein the successive graduations are proportional to the sine of the angular intervals from 0 to 90°, will simplify the determination of phase angles in many cases. In use, this scale is placed against the screen with its axes coinciding with the axes of the deflection system, and the deflections are adjusted so that they coincide with the 90° lines on the scale. This adjustment is easily accomplished by removing the deflecting potentials one at a time and adjusting the value of the other to the correct length.

The phase displacement is indicated directly where the trace intersects the axes, as shown in Fig. 13, where a 30° shift is indicated.

Continued on page 290

Automatic Control of Voltage and Current

Thirty-fourth instalment of "Electrical Measurements and Control." This series began in January 1934 (see editorial page of November 1933 issue). All rights reserved by the authors.

By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

6. Regulating Circuits utilizing Non-Linear Resistances.

The best-known example of the non-linear resistance is found in the conductor which varies its conductivity with temperature, and whose temperature is a function of the current which it carries. This principle is utilized in many ways in the regulation of currents and voltages. The simplest application is found in the "ballast resistance," usually in the form of a metallic filament enclosed in an evacuated or gas-filled envelope similar to an incandescent lamp, and inserted in series with the circuit to be regulated. A rise in the supply voltage tends to increase the current in the circuit, including the resistor, which increases its temperature, with a corresponding increase in resistance, so that the circuit as a whole does not follow Ohm's law.[31] It is obvious that such a system cannot give perfect regulation, and that a specific value of resistor would be required for every value of load. The principle, however, has a useful application, and has been widely applied in devices ranging from the Nernst lamp of several decades ago to some of the most modern radio circuits.

The self-regulating properties of heated conductors may be utilized more effectively than in the simple series circuit by combination into what is commonly known as a temperature bridge[32]; and this network may be used either to minimize or to amplify changes in the value of the applied voltage. When used directly for the regulation of voltage, the circuit takes the form of a four-armed bridge having one arm, or two opposite arms, of a high temperature coefficient of resistivity (generally incandescent lamps with metal filaments) and the remaining arms of fixed resistance. Line voltage is applied to one pair of opposite corners of the bridge and regulation is effected at the other pair. The performance of the lamp bridge differs from that of the bridge circuit as used in cold-end compensation of pyrometers[33] or in temperature compensation of instruments,[34] in that the sensitive arms operate at a high temperature due to current flowing in them, and that the temperature changes with changes of voltage are so much greater than normal variations in ambient temperature as to make the latter in most cases negligible.

The regulating properties of the lamp bridge are used in two ways, one in which the bridge is essentially unbalanced and a regulated current is drawn from the network, and the other in which the bridge is balanced at a selected voltage value, and unbalance conditions consequent upon voltage changes are utilized for regulatory purposes. The first of these methods is essentially limited in its application to those uses where it is desired to draw a small current of constant value from a variable-voltage source.[35,36] The respective arms are so proportioned that with a certain value of current flowing any change of voltage will tend to disturb the balance in a sense to oppose at the "output" terminals the change at the "input" terminals.

The broadest application of the lamp bridge is that in which the network is balanced at the value to which it is desired to regulate, and the unbalance current is caused to act in some form of relay circuit or mechanism. This network seems to have originated with Bradley over half a century ago,[37] and was made the basis of a number of practical circuits in measurement and control by Howell[38] some years later. It was used by Edison as a voltmeter and in 1918 Alcutt described[39] a potentiometer employing a similar bridge in lieu

[31] T. H. Amrine, Incandescent Lamps as Resistances: *Transactions A.I.E.E.*, Vol. 31, 1912, pages 1525-1535.
[32] Albert Campbell, On Test-room Methods, *Journal Institution of Electrical Engineers*, Vol. 30, 1901, pages 889-908. (For constant-voltage bridges, pages 900-904 only.)
[33] M. F. Behar, Temperature Measurement and Control, Instruments Publishing Co., Pittsburgh, 1932; Fig. 78, page 158.
[34] *Instruments*, April 1936, Fig. 46-1, page 117.
[35] Paul MacGahan, Circuit Voltage Regulator, *Electric Journal*, Vol. 29, Oct. 1932, page 489.
[36] James Spencer, A Current Stabilizer for Instrument Calibration, *Instruments*, Vol. 6, 1933, page 93.
[37] U.S. Patent 280,563, C. S. Bradley, July 3, 1883.
[38] J. Howell: U. S. patents 339,058 (March 30, 1886), 356,041 (Jan. 11, 1887), 356,042 (Jan. 11, 1887).
[39] C. A. Allcutt, A New Standard of Current and Potential, *Transactions A.I.E.E.*, Vol. 37, part I, 1918, pages 167-173. Discussions on pages 183-188, one discusser being Campbell (see ref. 32 above).

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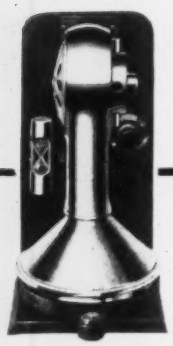

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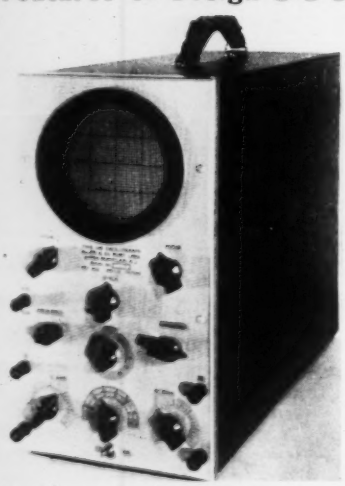

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of a cadmium standard cell for standardizing the slide-wire current, claim for his method an accuracy of 0.1%. A more modern portable potentiometer employing a temperature bridge is commercially available.*

The general principle of the lamp bridge will be understood by reference to Fig. 48-29 in which L and R represent metal filament lamps and fixed resistors respectively. A voltage applied to opposite corners of the network as shown will cause a current to flow through all arms of the bridge, heating the lamps, and bringing their resistances to values corresponding to the current

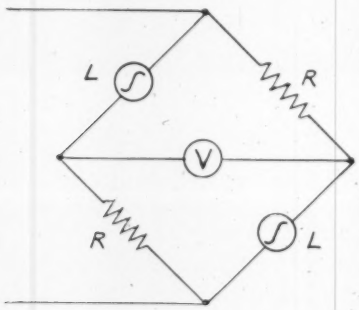


Fig. 48-29

flowing in them. It is obvious that if the network is adjusted to be balanced with a certain definite voltage applied, a change in voltage will alter the resistance of the lamps without affecting that of the other arms, thus upsetting the balance and causing a potential to be applied to the terminals of instrument V. It will be further apparent that the polarity of this potential as related to that of the supply will depend upon whether the latter has increased or decreased. Thus, the voltage at V reflects to an exaggerated scale any change in the line voltage and may be used in a suitable relay mechanism to command a controlling device.[40] This principle has been used satisfactorily for many years in the regulation of voltage for lamp testing.

The lamp bridge is effectively used in conjunction with an electronic amplifying circuit in a carbon-pile regulator used by the Safety Car Heating and Lighting Co. for excitation control, as shown in Fig. 48-30. The unbalance

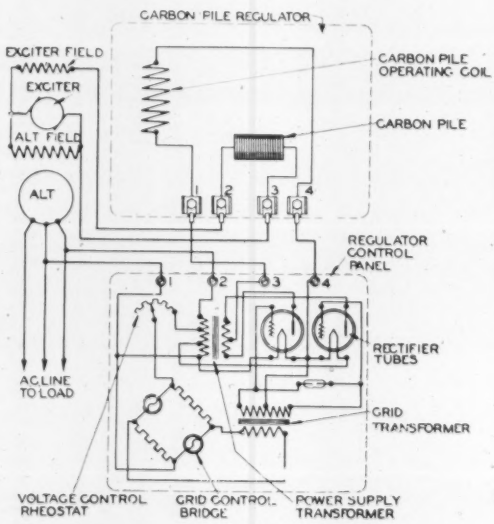


Fig. 48-30

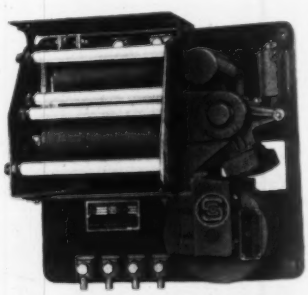


Fig. 48-31

current in the bridge serves to control the grid of one of a pair of rectifier tubes, according to whether the voltage is above or below the set value. The plate current derived from the tubes acts directly on the coil of a magnet governing the pressure on the carbon pile, which is connected in the main or exciter field of the machine to be controlled. The general appearance of the mechanical element of this regulator, including the carbon piles, is shown in Fig. 48-31.

There have been developed a number of regulating systems wherein the lamp bridge functions as a primary sensitive element, its responses being am

*See page 273 of this issue.

40 A. W. Hull, Hot Cathode Thyratrons, Part 2, Operation, *G.E. Review*, Vol. 32, 1929, pages 390-399.

...fied and rectified by other static devices, and the direct current so obtained ...lized either where a regulated unidirectional current is required or as a ...rce of excitation for a generator. For a discussion of the essential principles ...olved in combinations of the saturable cored reactor with the electron tube ...d the lamp bridge, the reader is referred to an A.I.E.E. paper by Austin and ...per.[41] A high degree of refinement in combined regulation and rectification ...shown in a recently issued patent,[42] wherein it is claimed that by various ...mbinations of a lamp bridge, a saturable reactor and a rectifying circuit, ...ere may be derived from a commercial a-c. service a voltage of sufficient ...nstancy to permit its use as a source of slide-wire current in the measuring ...ystem of a recording potentiometer.

An interesting combination of the non-linear bridge with the saturable-cored ...actor for regulation of voltage on a small a-c. feeder is described in a recent A.I.E.E. paper by Odessy.[43] Though only an experimental model is shown, it appears to possess over most types of small feeder regulators utilizing saturation the advantage that the secondary voltage is not subject to extreme distortion of wave form.

Applications of the non-linear resistance bridge in regulation have been materially extended by a recently developed material known as "Thyrite," an inorganic ceramic compound which has the remarkable property of changing from an insulator to a conductor as the applied voltage exceeds a critical value. This material was originally developed for use in lightning arresters.[44,46] The current through it increases 12.6 times for each doubling of voltage. It will be apparent that a bridge circuit similar to that shown in Fig. 48-29, or in any of its embodiments in voltage regulators, using Thyrite instead of heated conductors, may be made to perform the functions of the lamp bridge as a voltage-sensitive element, and to provide a definite and instantaneous response to variations in a voltage to be regulated.

7. Current Regulation.

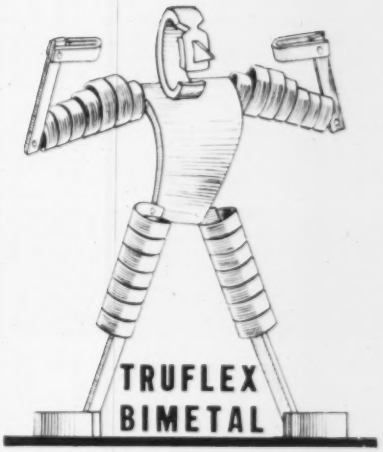
Present-day standard methods of electrical energy distribution are based on the maintenance of a constant voltage at a selected point in the system. In the early days of electrical development, before it had become apparent whether constant current or constant voltage would be the ultimate form, many ingenious devices were produced for regulating the line current to a constant value, these being particularly numerous in the field of series arc lighting. Though the essential principles of regulation are to a great extent applicable to both current and voltage control, most of the basically constant-current regulators have disappeared or are now found only in rudimentary forms in other classes of automatic regulators. Constant-current systems are still found in certain classes of lighting circuits; and for this purpose it is generally possible to employ the inherently self-regulating properties of some types of transformers, or else make use of reactors depending for their characteristics upon the saturation properties of their magnetic circuits.

(*Note*: The regulation of current for welding purposes is essentially a feature of design of generators or transformers, and does not come within the scope of Instrumentation.)

A survival of the earliest developments in constant-current practice is found in the constant-current transformer; and, while in the true sense of the word it is not an *instrument*, yet in the interests of completeness, and since it combines to a degree that function of an instrument with that of a power translating device, its well-known principle will now be reviewed.

The constant-current transformer embodies the essential elements of an a-c. transformer—a primary coil, a secondary coil, and a common magnetic circuit—having the magnetic circuit designed for high magnetic leakage and the two windings made relatively movable. Fig. 48-32 shows one form, in which the primary coil is stationary at one end of the magnetic system, the secondary coil being free to move vertically in the "window" of the core, and being more or less balanced by a counterweight. Because of the high magnetic leakage across the air gaps of the core, the voltage set up in the secondary coil will depend upon the position it occupies, being greater the nearer the windings are together. Since the primary and secondary currents in any type of transformer are opposite in direction, it follows that any current flowing in

[41] T. M. Austin & F. W. Cooper, Applications of Non-Linear Circuits, *Transactions A.I.E.E.*, Vol. 53, 1934, pages 293-296.
[42] U.S. Patent No. 2,032,455, A. J. Williams, March 3, 1936.
[43] P. H. Odessy, A D-c. Controlled Voltage Regulator, *Electrical Engineering*, Vol. 55, 1936, pages 956-960.
[44] K. B. McEachron, Thyrite, A New Material for Lightning Arresters, *Transactions A.I.E.E.*, Vol. 49, 1930, pages 410-420.
[45] U.S. Patent No. 1,822,742, K. B. McEachron, Sept. 8, 1931.
[46] P. Sporn & G. G. Langdon: Voltage Regulators, *Electrical World*, Vol. 105, May 11, 1935, pages 28-30.



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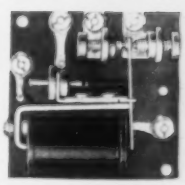
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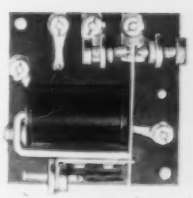
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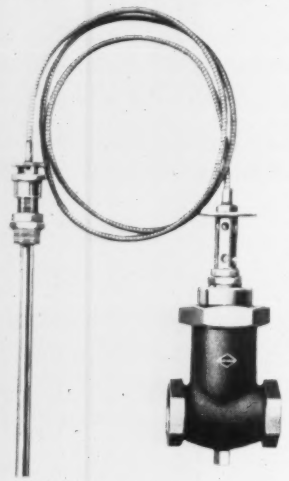

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the secondary winding will tend to set up a repelling action against that of the primary. There will thus be a tendency for the coils to be forced apart and this will vary with the intensity of the current. As the coils move apart the secondary rises and passes progressively into a region where it links with a weaker flux, so that there will be established a position of balance where the mechanical forces due to gravity will balance the electromagnetic forces. In case of the impedance of the external circuit decreasing, there will be a tendency for the secondary current to increase, increasing the repulsive action, forcing the secondary coil to a higher position, and thus reducing the induced electromotive force in the winding, and reëstablishing the balance with substantially the original current value flowing through the changed impedance of the load circuit.

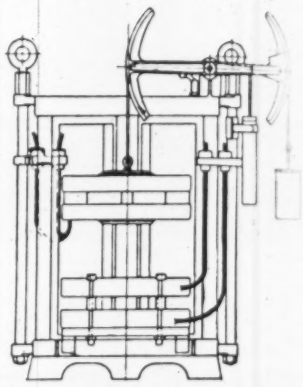

Fig. 48-32 (G.E.)

The regulation curve of the constant-current transformer can be considerably modified by altering the shape or the position of the quadrants upon which runs the cable supporting the counterweight. Sudden surges and "pumping" are eliminated by means of an oil-filled dashpot attached to the balance arm. In some forms of constant-current transformer the element of dead weight is eliminated by making both the primary and secondary coil movable, and balancing one against the other, the position of maximum mutual induction being found with both coils close together at the middle of the center leg of the core. The efficiency of constant-current transformers is generally high, but the power factor is likely to be low—seldom over 80% under the best conditions. These transformers are available in a great variety of sizes and types and are built both for air cooling and for oil immersion.[47]

8. Series Capacitors as Regulators.

Though the regulation of feeder voltages on alternating-current distribution systems can hardly be said to come within the field of Instrumentation any more than the utilization of the saturation characteristics of d-c. generators to establish normal operating voltages, yet neglect of the possibilities to be found in this relatively new and extremely simple manner of controlling line potentials would render incomplete the picture the authors are trying to present.

The shunt capacitor as a regulator of power factor is well known to distribution engineers. Although the ability of the series capacitor to maintain voltage on a supply line is obvious to students of electrical engineering, the practical application of the principle has been delayed by the lack of capacitors providing the necessary capacitance at a reasonable cost, and by the difficulty in protecting the units against abnormal voltages occurring under short-circuit conditions. These problems have found a solution in the development of a filling and impregnating liquid known by the trade name "Inerteen," which, in combination with paper, has a specific inductive capacity equivalent to that of mica.[48]

Capacitors of this type are connected in series with the line to be regulated, and protection against abnormal voltages due to short circuit conditions is afforded by a special type of spark gap. The capacitor produces a leading voltage proportional to the current flowing, and this combines with the line voltage in a manner to produce a high degree of compensation for drop due to loading of the circuit. In favor of this system of regulation, there are cited the following three characteristics of the method: (1) It is a current-operated system; (2) It is instantaneous in operation; (3) It produces wattless current *i.e.*, compensates for inductive loading, and thus tends to improve power factor.

A series capacitor, being current operated, cannot compensate for variations in bus voltage caused by conditions external to the feeder in which the capacitor is connected; but its property of instantaneous action makes it particularly desirable for eliminating flicker of lights due to voltage dips that ordinarily occur when large motor units are connected to the line.[49]

47H. C. Louis & A. Albaugh, Constant-current Regulating Transformer Characteristics. *Trans. A.I.E.E.*, Vol. 46, 1927, pages 77-83.

48R. E. Marbury, Inerteen Power Capacitors. *Electric Journal*, Vol. 33, Feb. 1936, pages 107-110.

49R. E. Marbury & W. H. Cuttino, Series Capacitors. *Electric Journal*, Vol. 33, March 1936, pages 145-149.

INSTRUMENTS' BOOK SHELF

Electromagnetic Oscillatory Circuits (Hochfrequenztechnik, I—Elektromagnetische Schwingungskreise.) By J. Kamlooser. C. F. Winter, Leipsig, 1936. Paper, 5⅞x8¼ inches, 172 pages. Price 9.60 RM.

This book gives carefully worked out derivations of the equations governing the behavior of high-frequency circuits. In his preface, the author sets forth his purpose as follows: "The book is intended to serve the high frequency engineer as a connecting link with physical fundamentals and to show him how he can apply these in his practical work."

This first volume of a series on high-frequency work contains chapters on condensers, coils, closed and open oscillatory circuits and the power losses to which they are subject. Workers in radio or allied fields will find it a valuable reference book giving the principles and assumptions underlying their design formulas. Ease of reference is somewhat impaired by the lack of an alphabetical index.

—L. T. Bourland, *Research Laboratories, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.* (4.1)-B-

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A Laboratory Manual of Experiments in Physics. By Leonard Rose Ingersoll and Miles Jay Martin. Fourth Edition. McGraw-Hill Book Co., New York, 1936. Cloth, 5½x8¼ inches, 301 pages. Price $2.50.

The two new experiments which have been added in this edition are welcome additions and bring this laboratory manual quite up to date, since it was completely revised four years ago.

It is an excellent manual for use in college physics courses. The wide variety of experiments and the splitting of the longer experiments into parts makes it easily adaptable to either technical or non-technical students. The theory and the thought-provoking questions accompanying each experiment are desirable features.

The introductory chapter on laboratory procedure and treatment of data is good—though the authors continue to advocate the method of averaging (pages 6 and 7) when the least-squares formulas are almost as easy to use and just as easy to understand. The method of averaging given in the manual is particularly bad when applied to acceleration experiments as suggested in the note on page 33, since it discards all but three of the observations. However, this fault is shared by the majority of this type of laboratory manuals and, therefore, cannot be considered a serious criticism.

—Emerson M. Pugh, *Associate Professor of Physics, Carnegie Institute of Technology, Pittsburgh.* (1.2)-B-

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Photo-voltaic Cells and Their Applications. (Die Photoelemente und ihre Anwendung) By Bruno Lange. Johann Ambrosius Barth, Leipzig, 1936. Paper, 6x9 inches. Vol. I, 132 pages, price 9.60 RM. Vol. II, 94 pages, price 6.75 RM.

Dr. Lange contributes a welcome addition to the literature on the interesting and timely subject of photo-voltaic cells in these two workmanlike little volumes which are packed with useful information couched in easily readable German.

Part I, "Entwicklung und Physikalische Eigenschaften," deals with the development and the physical properties of photo-sensitive materials. The introduction contains a survey of photoelectric fundamentals and discusses briefly the outer photo-effect and alkali photocells, the inner photo-effect, photoelements and photo-resistance. Chapter I concerns itself with the historical development of the photoelements under the headings, Electrolytic photoelements, Semi-conductor photocells, and Crystalline photoelements.

In Chapter II Dr. Lange discusses at some length the various theories concerning the semi-conductor photo-effect. In this discussion he shows "that the normal photo-e.m.f. in barrier-layer cells is determined by the concentration relation of the electrons in the barrier layer and the semi-conducting layer, corresponding to the emission centers there present. On the other hand, in the case of crystalline cells, it is determined by the relation of emission centers at the entrance point of the light and the low electron concentration on the unilluminated back wall. In the barrier layer no or only few emission centers are present which lead to a rise in electron concentration when illuminated. On the posterior side of the crystal emission centers are present but no light to liberate electrons. The photo-e.m.f. of both forms of cell is therefore . . . not essentially different." Dr. Lange goes on to show that the photo current in the two forms of cell is very different, however, resulting from differences in path resistance inherent in the crystal and in the barrier layer.

Chapter III deals with the physical properties of semi-conductor cells, special attention being given to temperature dependence, sensitivity in the visible spectral region, the effect of polarized light, X-ray sensitivity, the effect of cathode rays, the effect of a magnetic field and frequency dependence.

Part 2, "Technische Anwendung," concerns itself first with structure as well as sensitivity and performance. Chapter II then discusses photo-electric photometry in which constancy, linearity, temperature effect and visual sensitivity are taken up before going into the various forms of light meters for the visible spectral region, photometers for the ultra-violet and X-ray regions, and other similar equipment. Chapter III deals with exposure meters for photographic use; Chapter IV with special photometric apparatus; Chapter V with the remote transmission of coarse measurements; Chapter VI discusses the matter of amplification and Chapter VII photoelectric switching and signaling.

Dr. Lange concludes this treatise with a chapter on the applications of photo-voltaic cells in various scientific fields and their use as sources of energy.

While Dr. Lange has drawn largely from his own extensive work in this field he has incorporated in these volumes the results and ideas of other workers to which due credit has been given in the rather comprehensive bibliography appended. We repeat that these volumes are a welcome addition to the literature on the photo-voltaic effect and its applications.

E. F. Lowry, *Director of Research and Development, Continental Electric Company, St. Charles, Illinois.* (5.3)-B-

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Amplifiers. (Verstärker) By H. Barkhausen. Fourth edition, S. Hirzel, Leipzig, 1933. Cloth, 6x9 inches, 289 pages. Price 9 RM.

This volume is the second of a series of three ("Elektronen Röhren") covering the entire electron-tube art. The first volume covers completely tube theory, characteristics and design; the volume now under review treats the whole field of amplifiers; the third volume (reviewed here last May, page 132) is a complete treatment of oscillators. The author appropriately divides amplifiers into three main classes each requiring a basically different design treatment: (1) preamplifiers, in which the main design requirement is high amplification with extremely small initial power; (2) power amplifiers, in which the primary objective of design is to achieve the maximum output of undistorted power from standard tubes; and (3) the high power or transmission amplifiers, where high efficiency, to limit tube heating and secure operating economy in power costs, is the primary objective of design.

The author's technique of treating each class of amplifiers is to consider first the no-load condition (infinite plate load resistance) and the full-load condition (plate load resistance zero). Simple formulae are deduced evaluating the principal elements at these extreme (no load and full load) conditions. In terms of these extremity

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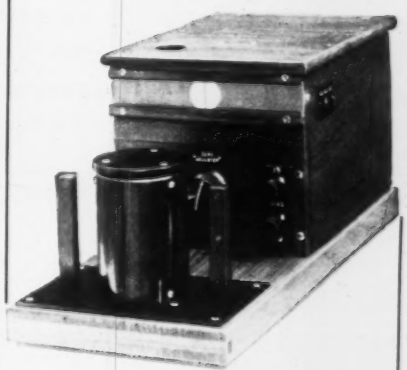

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values practical, simple expressions are deduced for estimating the value of any required design factor anywhere in the range between. For example, for power amplifiers a "distortion" factor is deduced, based on distortion at no load and full load, which readily evaluates the amount of distortion to be expected (under a given set of operating constants) for any other load. This method brings out amplifier design considerations with a simplicity and clearness not even distantly approached by other texts.

Nearly half of the volume is devoted to "Theory of Circuits"—a comprehensive study of circuit elements, their characteristics and requirements as coupling elements between tubes. Merely a list of the section headings for Chapter II will indicate how thorough and complete, yet well-ordered and understandable this treatise is: (1) Boundaries of distortion-free operation: grid voltage factor; plate current as a factor. (2) The plate current distortions with constant D (D is reciprocal of amplification factor). The graphic problem; development by Taylor series. (3) "Distortion-freeness" factor and modulation factor. Definition of "distortion-freeness" factor; approximate formulae; measurement by bridge methods. (4) Distortions with varying D. Development by Taylor series; first approximation; second approximation. (5) Best position of the operating point. Three rules; graphical construction; table. (6) Deductions. Minimum plate potential requires corresponding minimum D; boundary curve of maximum permissible plate load. (7) Multi-grid tubes. (8) Push-pull arrangement. (9) Summary of power amplifiers.

The printing is clear, the diagrams well drawn.

On the whole this volume is a masterful treatise; one that leads the beginner into a sound, basic grasp of the whole subject of amplifiers; and to the veteran radio technician's mind brings a more unified, comprehensive view of the subject than he had before.

—H. Olken, *Director, Development Dept., Industrial Control Instruments Co., Cambridge, Mass.* (5.4)-B-

How to Build up Furnace Efficiency. By Jos. W. Hays. Dunes Publishing Co., Michigan City, Ind., 18th Ed. 1936. Cloth, 5½ x 8 inches, 559 pages. Price $3.00.

This book discusses combustion in popular language, readily understood by the fireman—but will also interest the combustion engineer and power plant operator.

Charts and diagrams are used to clarify certain statements, while cartoons are used rather liberally to emphasize some of the arguments. The instruments and apparatus illustrated are those designed by the author and manufactured by the Hays Corp.

A great many anecdotes are related in the book to illustrate points that the author feels should be brought out with some emphasis.

Richard Rimbach (2.07)-B-

Handbook of Steam Flow Measurement. By L. K. Spink. Published by The Foxboro Co., Foxboro, Mass. Second edition, 1936. Paper, 5¼ × 7¾ inches, 70 pages. Free to power-plant engineers and others concerned with problems of steam flow.

Since its publication in 1931, the 48-page first edition has become almost a standard reference. This edition, containing 50% more pages of text and tables, should prove even more useful, not only to power-plant engineers but to those who have charge of processing applications and especially to engineers who use steam under varying pressures and temperatures. Defects in the typographic make-up, which we pointed out in our review of the first edition, have not been corrected. However, they do not lessen the book's value as a source of information.

—M. F. Behar (2.05)-B-

Television Reception. By Manfred von Ardenne; translated by O. S. Puckle. Chapman and Hall, Ltd., London, 1936. Cloth, 5½ × 8⅝ inches, xvi + 121 pages.

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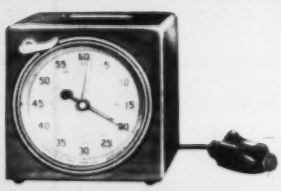

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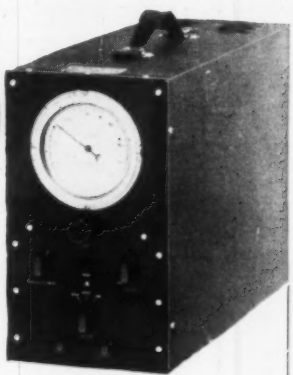

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—R. R. Batcher, *radio engineer, cathode-ray application specialist, Hollis, L. I., N. Y.* (5.3)-**B-**

Chemical Engineering Catalog. 21st Edition. Reinhold Publishing Corp., New York, 1936. Cloth, $8\frac{1}{2} \times 11\frac{1}{4}$ inches, 913 pages. Price $10.00, except to special classes of technical men to whom it is lent gratis or sold for $3.00.

Autumn rolls around again and with it comes this annual, containing 'even more pages of data from firms that use this means of bringing their products before prospective purchasers. It always has been the publishers' policy to encourage advertisers to give detailed and actually useful information so that each year the Catalog comes nearer to its goal: an absolutely complete and reliable source of information for the whole group of process industries. The sections are the same this year as last, namely: Trade Name Index; Equipment and Supplies; Chemicals and Raw Materials, and Technical and Scientific Books. Careful cross-indexing makes the volume easy to use.

—M. L. Moorman, *Associate Editor, Metals & Alloys, Pittsburgh, Pa.* (12)

Author of "Theory of Alternating Current Wave Forms" Comments on Critical Review (*Instruments*, March 1936, pages 87-89).

To the Editor of *Instruments*:

It is not my practice to reply to reviewers' criticisms, but in the present case I feel that certain points call for comment. The lengthy criticism of your reviewer is based, he says, on a hurried reading of the book. It is to be regretted that this, apparently, did not include a perusal of the preface, for there it states "The subject is treated generally without reference to specific machines or types of apparatus, but it is hoped to include such matter in a later volume." The reviewer's complaint that "the effect of non-sinusoidal currents and voltages upon rotating machines is barely mentioned" is therefore irrelevant. Similarly, he says that "the importance of harmonics in connection with rectifiers and rotary converters receives scant mention." The writer cannot find any mention of them at all. The same applies to your reviewer's remarks about the influence of harmonics on the nature of windings of machines. In view of the statement in the preface, quoted above, no apology is therefore needed.

It is not proposed to reply to the detailed criticism which follows as, in a number of instances, it involves a matter of opinion, and your reviewer is entitled to hold whatever view he wishes. Most differences of opinion finally resolve themselves into differences in the definition of terms.

Evidences of the truth of his statement that his reading of the book was hurried are, however, not lacking. For example, he sees an equation on page 55, and says that so fundamental an error is sufficient to discredit the whole book, overlooking the very next sentence which says that the equation does *not* give a useful approximation.

Whilst the writer accepts some of your reviewer's corrections, he cannot agree with him on many points and must reserve the right to adhere to his own opinions.

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 (Continued from page 293)

Another method of measuring the phase displacement, when for some reason the intercepts are not clear, is to measure the angle between two radii, drawn in to intersect the points of contact of the ellipse with two tangents drawn perpendicular to each axis.

PHASE STUDIES WITH CIRCULAR DIAGRAMS

A method whereby phase angles can be determined with greater accuracy has been disclosed by Marrison[14] and by MacLean and Sivian[15]. It is in effect a measurement of the time elapsing between the maxima of the two waves. Here a circular diagram is produced, using a rotator circuit to which the reference wave is connected. A sharp pulse is introduced into the anode circuit (or when available in the cathode-ray tube used, into either its focus electrode circuit or the modulation grid circuit), by the action of the second frequency. In order that possibly large variations of the voltage of the latter frequency do not complicate the measurements,

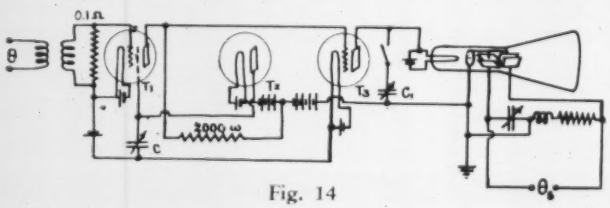


Fig. 14

a special pulse generator is used for this purpose which is triggered off at the correct instant by the potential wave being studied. The circuit is shown in Fig. 14.

In another circuit shown by Marrison[16], used for the determination of the phase shift through certain telephone circuits and networks, a reference frequency is used to supply a circular time base as above and is also connected to the network under test. The output of the network is connected to a pair of deflection coils which are rotated around the cathode-ray tube until the phase shift is neutralized on the diagram.

PHASE STUDIES WITH SUPERPOSED DIAGRAMS

A simple arrangement, useful in illustrating phase relations, resonance and other characteristics of circuits, has been used by the RCA-Victor Co. in educational lectures for radio service men. A vibrator of the type used in auto radio receiver power supply systems is used in conjunction with one oscillograph (or several) to show a number of circuit effects wherein current and voltage waves are superimposed in their proper phase relation. This vibrator is so connected that it rapidly switches two portions of the circuit alternately to one pair of deflection plates, as shown in Fig. 15. Such a vibrator (depending upon the make and adjustment) operates 60 or 80 times a second. In order that complete waves be shown, the phenomena under investigation must be connected to a frequency source higher than the vibrator frequency. The RCA uses a frequency higher than audibility during these demonstrations. Fig. 15 has been adapted from the circuit which they have found most useful, and represents a combination of several separate tests. An alternating current is applied to a coil inductance or a resistance through a current shunt R_s. The current through this shunt produces a voltage drop which is applied to the deflection plates through the test

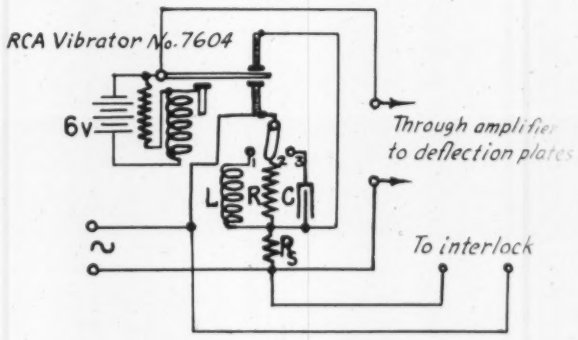


Fig. 15

set of contacts on the vibrator, incidently being amplified by the internal amplifier in the "Type TMV 122B" oscillograph. During the alternate closure within the vibrator the drop across L, C, or R is depicted in the same way, the switching occuring at so rapid a rate that both curves appear superimposed to the eye.

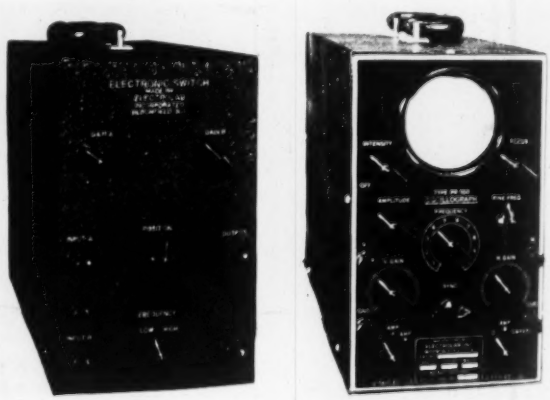


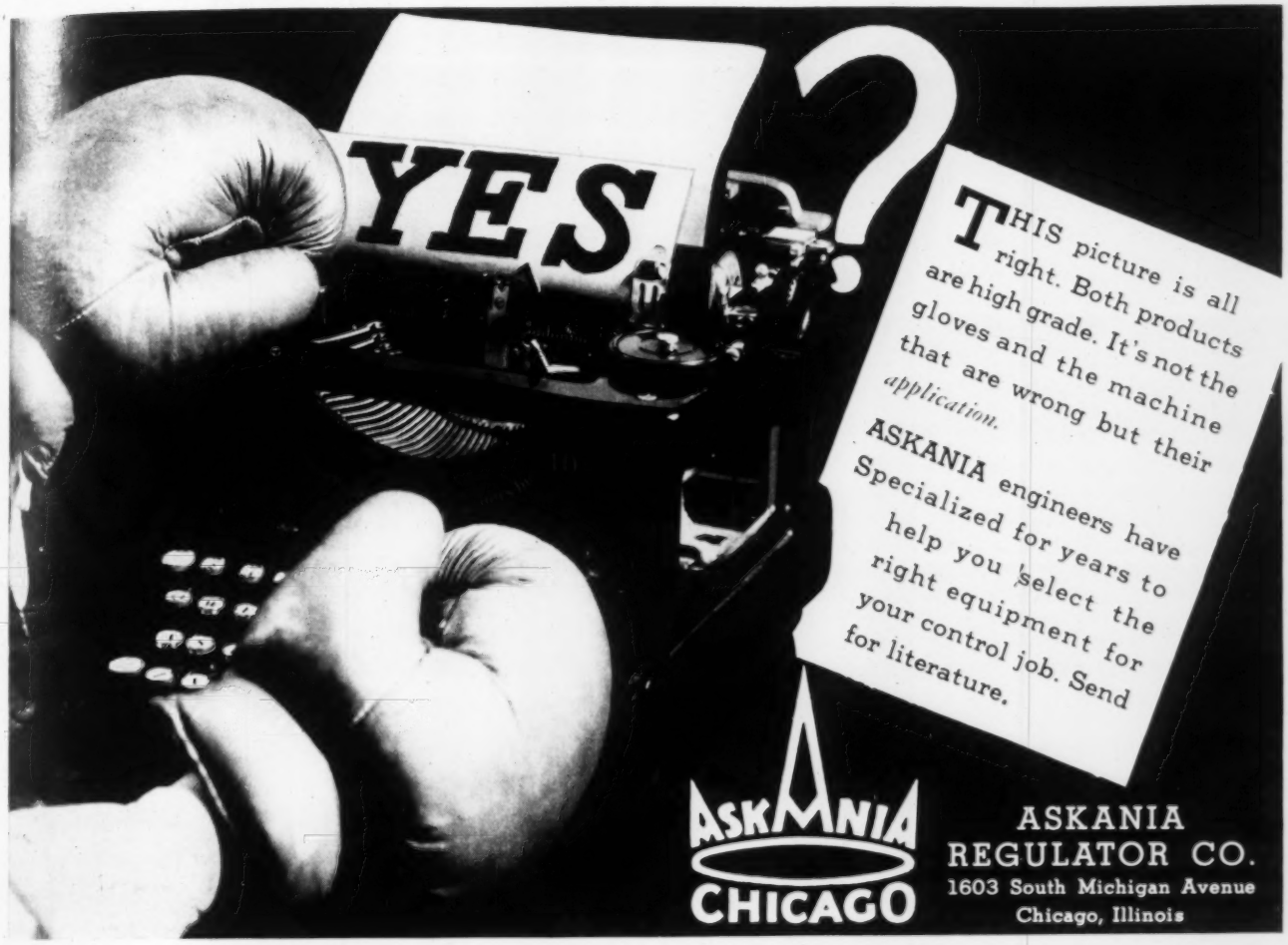
Fig. 16

Other electronic switch devices, described in the March article under the heading of Multiple Diagrams, will accomplish the same thing with a wider and more flexible range of switching frequencies. In these devices the change from one wave-form to the other occurs at an extremely rapid rate, so fast that the visible lines are in reality each made up of a series of dots or short dashes. The movement from one trace to the other is so rapid, it is claimed, that it remains invisible during the changeover interval, a matter of one microsecond.

In this way it is not necessary that the electronic switch operation be synchronous with the wave sources under investigation, and all phase displacements are correctly delineated. It is necessary that any deflection amplifiers when used with this equipment, be designed to pass not only the frequencies under investigation, but also a radio frequency switching frequency as well. Fig. 16 illustrates a switch of this type from Electrolab, Inc., in conjunction with their cathode-ray oscillograph.

To Be Continued

[14]Marrison. Phase-shifting System. U. S. Patent No. 1,942,483.
[15]MacLean & Sivian. Direct-reading Audio-frequency Phase Meter. *Journal Acoustical Society of America*, Vol. 1, 1931, pages 419-433.
[16]Marrison. Phase-measuring Circuit. U. S. Patent No. 1,768,262.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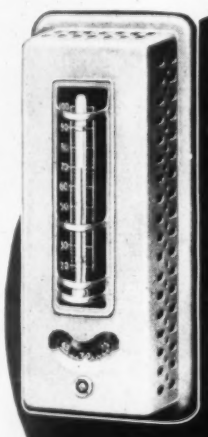

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D291 **Dial Gages.** 8-page 8½ × 11" bulletin is devoted to the new "Shockless" line and describes in detail the improved construction. B. C. Ames Co., Waltham, Mass.

D292 **Micrometer.** Leaflet describes new design with narrow anvil end and deep opening. Brown & Sharpe Co., Providence, R. I.

D293 **Universal Automatic Control Mechanism.** 4-page Bulletin No. 200 describes "Dunkool" Condition Controller which has a standardized body, the front plate carrying various measuring elements. Dunkool, Inc., 1010 N. Main St., Elkhart, Ind.

D294 **Oil Circuit Breakers.** 1-sheet section 5 of Catalog 6 describes "Turbulator" line of indoor type breakers. RollerSmith Co., 2132 Woolworth Bldg., New York, N. Y.

D295 **Low Water Cut-Off.** Form 9167 describes a built-in type of liquid level switch. McDonnell & Miller, Wrigley Bldg., Chicago, Ill.

D296 **Beloptícons and Accessories.** 24-page Catalog E-11 discusses underlying principles, describes the instruments themselves, and gives notes on their use. Also a smaller publication, 8-page Bulletin E-153, prepared for educators. Bausch & Lomb Optical Co., 615 St. Paul St., Rochester N. Y.

D297 **Industrial Thermometers.** 4-page Bulletin 90023 describes a line of industrial thermometers in which the glass tubing is of a radically new form, with a wide reading angle hence called "Bimac" signifying binocular vision. Taylor Instrument Cos., 93 Ames St., Rochester N. Y.

D298 **Platter Type Scales.** 2-page bulletin describes new "Shadowgraph" scale in which conventional indicating lower mechanism is replaced by illuminated dial. The Exact Weight Scale Co., Columbus, O.

D299 **Resistors, Bridges, etc.** Coat-pocket-size loose-leaf catalog gives characteristics and specifications of precision wire wound resistors, decade resistance boxes, bridges, test equipment and switches. Shallcross Mfg. Co., Collingdale, Penna.

D300 **Industrial Electric Control.** New loose-leaf catalog, containing more than 100 sheets and provided with colored tabs, covers complete line of field rheostats, manual and automatic d-c. and a-c. starters, contactors, transfer switches, etc. Ward Leonard Electric Co., 38 South St., Mount Vernon, N. Y.

D301 **Round-chart Recording Voltmeters and Ammeters.** Bulletin No. 136 covers a new line for electric utilities and industrial plants, including models for wall, switchboard, flush panel, and pole mounting, as well as for portable use; describes new inverted type replaceable movement and novel design of the pen arm. The Bristol Co., Waterbury, Conn.

D302 **Voltage Regulators.** Sections 1, 2 and 3 of Catalog 10 cover new booster voltage regulators, step capacitor regulator controller and step voltage regulator controller. Roller-Smith Co., 2132 Woolworth Bldg., New York, N. Y.

D303 **Air Circuit Breakers.** 16-page Section 3 of Catalog 5 covers new "Type BD" and presents a detailed engineering discussion. Roller-Smith Co., 2132 Woolworth Bldg., New York, N. Y.

D304 **Universal Testing Machines.** Loose-leaf 9" × 11½" Catalog 50 Part L, divided into 7 sections including pendulum weighing hydraulic and screw power machines, hydraulic-support and packless-cylinder hydraulic machines, beam-weighing screw power machines, etc. Tinius Olsen Testing Machine Co., 500 N. 12th St., Philadelphia, Penn.

D305 **Vacuum Tubes.** 38-page, 5½" × 8" booklet covers vacuum tubes for use in amateur transmitting equipment, going into many engineering details. Western Electric Co., 195 Broadway, New York, N. Y.

D306 **General Radio Experimenter.** Vol. 11, Nos. 2 and 3 (July-August 1936) contain an article on noise measurement and a description of a new general-purpose amplifier. General Radio Co., 30 State St., Cambridge A, Mass.

D307 **Filter Glasses.** 16-page 12¼" × 9" Catalog 1892-E, describing Jena Colored Optical Filter Glasses for Scientific and Technical Purposes, will be sent to readers of *Instruments* requesting copies on company letterhead. Fish-Schurman Corp., 230 East 45th St., New York, N. Y.

D308 **Radio Instruments.** 4-page Bulletin, "Form 8-28-36" describes panel instruments, a new signal generator and a new radio analyzer called "Roto Ranger" by reason of its 12 independent scales combined with a range selector. Simpson Electric Co., 5216-18 W. Kinzie St., Chicago, Ill.

D309 **Dry Rectifiers.** 12-page 8½" × 11" booklet, "43-2078" describes selection and application of "Rectox" copper oxide rectifiers. Special application sheets for easily giving the requirements of a proposed use of Rectox are included with each booklet. Westinghouse Electric & Mfg. Co., East Pittsburgh, Penn.

D310 **Air Conditioning.** A handsome 16-page 8½" × 11" booklet contains a profusion of installation photographs as well as brief descriptions of instruments for air conditioning. Julien P. Friez & Sons, Baltimore, Md.

D311 **Metal-pouring Barometer.** Circular 646-1 covers applications of immersion thermocouple and round chart Micromax pyrometer. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Penn.

D312 **Thermocouple Accessory.** Circular N33A-2 describes a universal head for all base-metal couples. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Penn.

D313 **Checking Pyrometers.** 4-page Folder F-E142-1 describes portable potentiometers for checking pyrometers. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Penn.

Continued on page 300

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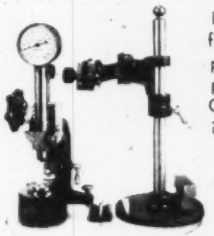

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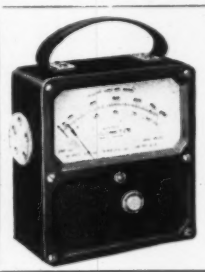

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INSTRUMENTS, published monthly at Pittsburgh, Pa., for October 1st, 1936.

Commonwealth of Pennsylvania, County of Allegheny, ss.:

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the publisher of INSTRUMENTS and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Publisher, Richard Rimbach, Pittsburgh, Pa.

Editor, M. F. Behar, Pittsburgh, Pa.

Managing Editor, Richard Rimbach, Pittsburgh, Pa.

Business Manager, Richard Rimbach, Pittsburgh, Pa.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) Richard Rimbach, Pittsburgh, Pa.

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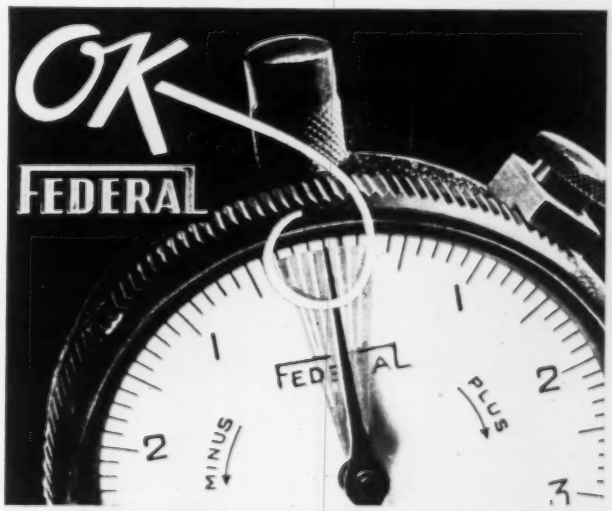

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